THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

BULLETIN No. 64

WEST WALKER RIVER INVESTIGATION

APRIL 1964

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The Resources Agency of California

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Governor
State of California

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DEPARTMENT OF WATER RESOURCES

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February 18, 1964

Honorable Edmund G. Brown, Governor
and Members of the Legislature
of the State of California

Gentlemen:

I have the honor to transmit herewith the final edition of Bulletin No. 64, "West Walker River Investigation." The preliminary edition of this bulletin was issued December 1957. The final edition incorporates both the results of the original investigation and those studies performed since 1958. This report presents an evaluation of the water resources and water requirements of the West Walker River Basin in California and reviews methods by which the water requirements of the area could be met within existing water supply and water right limitations.

Many perplexing water problems occur within the area of investigation. Because the West Walker River is an interstate stream, legal complications have been added to the usual engineering problems. The results of our studies show that the natural water shortage of the area could be partially alleviated by a water conservation project.

This report recommends that additional investigation of potential surface water conservation projects be limited to several sites. It also recommends that further investigation be made of the possible use of ground water storage.

Sincerely yours,

Director

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

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ACKNOWLEDGEMENT

During the course of this investigation, many public and private agencies and individuals provided considerable assistance and data. Without their help and cooperation, this report would not have been possible. Although these agencies and individuals are too numerous to list, their assistance is gratefully acknowledged.

Special mention is made of the assistance of Messrs. Ray Charlebois, George Koenig, Brooks Park, George Roberts, Mrs. Mabel Roberts, and Mr. and Mrs. Frank Spring, landowners in the Antelope Valley who contributed labor, equipment and materials for the investigation.

AUTHORIZATION

The West Walker River Investigation was authorized in the Budget Acts of 1955, (Calif. Stats. 1955, Ch. 777, p. 1320); 1956, (Calif. Stats. 1956, Ch. 1, p. 45); 1958, (Calif. Stats. 1958, Second Ex. Sess., Ch. 1, p. 519); and 1960, (Calif. Stats. 1960, Ch. 11, p. 74). The funds were appropriated for a survey of all lands in the West Walker River Basin in California. The principal purpose of the survey was to plan works for the conservation and development of water to supply the needs of the West Walker River area in California.

A preliminary report of this investigation was published in December 1957. The appropriations of 1958 and 1960 provided funds for studies of several reservoir sites recommended in the 1957 report. This report presents the results of the entire investigation from 1955 to its conclusion in 1963.

CHAPTER I. INTRODUCTION

The West Walker River has its headwaters high on the easterly slope of the Sierra Nevada near Sonora Pass and flows in a northerly course across northern Mono County, California, to the State's eastern boundary and beyond, into Nevada. As the stream moves through rocky canyons, narrow enclosures and wide, calm areas, it drains approximately 410 square miles in California and creates some perplexing water problems. These problems were of long standing when, in 1955, the ranchers within the West Walker River Basin in California requested the aid and assistance of the State. They had just endured two years of subnormal streamflow; the price of cattle had suffered a sharp drop; and a federal court had recently instituted strict regulation of the waters of the West Walker.

Acting through their legislative representatives, the local people requested the aid and assistance of the State of California to determine a solution to their water problems. The West Walker River Investigation was authorized by the Legislature in the Budget Act of 1955 (Calif. Stats. 1955, Ch. 777, p. 1320) and additional funds appropriated in 1956 (Calif. Stats. 1956, Ch. 1, p. 45). In December 1957, a preliminary report of the investigation was published. As a result of recommendations in the preliminary report, the Budget Acts of 1958 (Calif. Stats. 1958, Second Ex. Sess, Ch. 1, p. 519) and 1960 (Calif. Stats. 1960, Ch. 11, p. 74) contained authorizations for the further study of several small reservoir sites in the area. This report presents the results of the entire investigation and discusses possible solutions to the water problems of the area.

Related Investigations and Reports

The Lahontan Area, or Great Basin, in which the West Walker River Basin lies, has been the scene of investigation for many years. As early as 1881 teams of geologists, botanists, biologists, and other scientists, investigated the natural phenomena of the area[1/]. Since then the federal government, the State of California, irrigation districts, power companies, and others have investigated the area with regard to development of its water resources. The literature on the subject is both extensive and intensive. Those reports which were felt to be germane to this investigation were reviewed and, where applicable, data taken from them. These are listed in the bibliography at the end of this report.

In 1947, the monumental task of measuring the water resources of California was initiated. By 1957,

1/ United States Geological Survey, 3d Annual Report to the Secretary of the Interior, 1883.

three reports on the subject had been published. The first two of these, Bulletin No. 1, "Water Resources of California," and Bulletin No. 2, "Water Utilization and Requirements of California," published by the State Water Resources Board, were primarily presentations of the statistics concerning the water resources, water utilization and water requirements of California. Bulletin No. 3, "The California Water Plan," presented a broad, general plan for conserving the waters of the State, without attempting to describe any single project in detail. A plan for development of the West Walker River was included in that report. The present investigation and this report are, in a sense, a continuation of the plan outlined in Bulletin No. 3. This investigation and report has sought to translate the generalities of Bulletin No. 3 into specific projects for the conservation of the waters of the West Walker River.

A portion of the information contained in this report was obtained from studies of the water resources and requirements of the California portions of the Truckee, Carson, and Walker River Basins, made under a service agreement with the California-Nevada Interstate Compact Commission of California.

Interstate Compact Commission

Although the West Walker River Basin Investigation was limited to California, the basin extends into Nevada where the major portion of the current water use takes place. Because of overappropriation, the stream has been the subject of a great deal of litigation, culminating in a decree by the Federal District Court for Nevada (United States v. Walker River Irrigation District, et al, Equity No. C-125, D. Nev. 1936). Almost two decades of experience with this decree and its enforcement by a federal watermaster, led to the realization that an interstate agreement was needed in order to equitably distribute the waters of the Walker and the other interstate streams between the States of California and Nevada.

The California-Nevada Interstate Compact Commission of California was created to reach such an agreement. The commission consists of the Director of Water Resources and six members appointed by the Governor. Its function is:

> " . . . to cooperate with a similar commission representing the State of Nevada in formulating and submitting to the legislatures of both states for their approval an interstate compact relative to the distribution and use of the waters of Lake Tahoe and the Truckee, Carson, and Walker Rivers." (Calif. Stats. 1955, Ch. 1810, p. 3350; Government Code Section 8136)

A compact negotiated by the two commissions, approved by the legislatures of the states and consented to by Congress could resolve many of the existing water right problems and provide for an equitable apportionment of interstate waters between the States. The alternative to a compact, a decree of the United States Supreme Court in a suit for equitable apportionment, could have like effect, but might be accomplished only after protracted and expensive litigation. Such a suit has been authorized by Chapter 203, Statutes of 1961.

Scope of Investigation and Report

The original act authorizing the West Walker River Investigation provided for a complete water resources investigation, including water supply, requirements, quality, and preliminary project planning (Budget Act of 1955; Calif. Stats. 1955, Ch. 777, p. 1320). The terms of the act authorizing the investigation limited the studies to the California portion of the river system. The funds available dictated that the investigation be limited to a reconnaissance study.

Field work performed during the initial period consisted of soil classification; land use mapping; measurement of streamflow and diversions; reconnaissance of potential reservoir, conduit and powerplant sites; reconnaissance of areas in which ground water could be developed; reservoir site surveys, studies of agricultural production; sampling and testing of present water supplies to determine mineral quality; and the collection of data from public and private agencies.

Office studies were initiated concurrently with the field work. These studies, based on analysis of data collected in the field and from public documents, included hydrology, geology, water quality, water rights, present and future water requirements, preliminary design and cost estimates of potential water conservation projects.

This report presents an evaluation of the water resources and water requirements of the West Walker River

Basin in California and reviews various means by which the water requirements of the area could be met within existing water supply and water right limitations. The report recommends that further investigation of potential projects be limited to several specific sites.

Area of Investigation

The area of investigation is the California portion of the West Walker River Basin in northern Mono County.

The Walker River, the principal source of water for the entire basin, rises in two main branches--the East and West Walker Rivers, which are separated by the Sweetwater Range. The West Walker is the more important branch, supplying nearly twice as much water as does the East. The West Walker originates near the northern boundary of Yosemite National Park, from where it flows northward until it crosses the California-Nevada state line near Topaz Lake.

The West Walker River travels through a narrow canyon from its headwaters near Sonora Pass, passes through Leavitt Meadow and Pickel Meadow where pasture lands are irrigated and joins the Little Walker a few miles past the junction of Highway 395 and the Sonora Pass Road. The river is supplemented by waters from Cottonwood and Rock Creeks flowing from the western slope of the Sweetwater Range.

The largest community in the area is Coleville, located on U.S. Highway 395 about halfway between Bridgeport, California, and Minden, Nevada. Coleville is the principal urban center for the surrounding Antelope Valley, the largest valley in the basin. Approximately 11,000 of the 14,000 irrigated acres within the basin are located in the Antelope Valley.

Geology

The California portion of the West Walker River Basin is situated in the transitional zone between the Sierra Nevada and the Basin-Ranges geomorphic provinces. The boundary between the provinces is generally accepted as the great faults which traverse the western margin of Antelope Valley and the West Walker River gorge.

Although the area of investigation embraces both the Sierra Nevada and the block fault mountains and valleys to the east, geologic differences between these two provinces are generally not great in this area. Rocks found in the Basin-Ranges portion of the area are the same types as those of the Sierra Nevada. In general, the rocks consist of a core of crystalline intrusives and an older series of contorted metamorphics. The intrusive granitic rocks were emplaced in a region which consisted for the most part of slates, phyllites, and meta-volcanics. These metamorphic rocks have been strongly eroded and now form relatively limited outcrop areas in the region of investigation. Large volumes of volcanic flows were erupted during later times forming extensive volcanic terranes. The higher portions of the area where many of the volcanic flows occurred have subsequently been glaciated and glacial debris is common, though it does not make up any large proportion of the rocks of the area.

Structurally, the region is characterized by a series of parallel, northerly-trending normal faults of large displacement. All the intermontane valleys of the area are located along or between the faults where streams have been able to easily erode the shattered and strongly weathered bedrock. Damming of glacial moraines, landslides, and fault tilting has caused formation of intermittent lakes and deposition of lake sediments in many of the valleys. Thus, the ground water basins of the area are composed of a series of interbedded alluvial fans, flood-plain and stream channel deposits, and lake sediments. Although portions of some of the volcanic tablelands and glacial terranes are devoted to farming, by far the greater portion of the agriculture of the area is carried on in the alluviated valleys. Many of these valleys have high water tables due to the gentle slope of the ground surface, enclosure of the valley by essentially impermeable materials and, in some cases, high precipitation.

Climate

The climate on the eastern slope of the Sierra Nevada is extremely variable. Annual precipitation in the area of investigation varies from about 70 inches near the crest of the Sierra Nevada to approximately 6 inches in the desert regions near the state line. Summer temperatures are quite mild, rarely exceeding the low 90's in Antelope Valley, or the high 70's in the higher mountains. The winters are relatively severe and below-zero temperatures occasionally occur. In most years the growing season extends from late April to late September.

Economy

The principal industries in the area are agriculture, recreation, and forest products.

Agriculture has been the most important industry in the area since it was first settled in the 1850's. In the past, field crops such as beans and vegetables were produced in the area. These crops were mostly sold locally, the demand resulting from mining activity in the area. As the mining industry declined and with the advent of rapid and economical truck transportation, such crops were imported from other areas and local production ceased. Present crops are generally limited to forage used by beef cattle.

Today, owner-operated cattle enterprises, based on locally produced cattle replacements and the selling of weaner calves, is the principal livestock industry in the basin. The size of individual cattle holdings varies widely with some being smaller than the indicated minimum economic size of about 175 animals. Most of the cattle enterprises hold summer grazing permits on nearby National Forest lands which serve to supplement their pasture. Hay carryover is essential for feeding of the breeding stock that is retained in the valley during the winter, and all livestock enterprises which maintain cattle in the valley the year-round devote a portion of their land to the production of this crop.

The recreation industry is one of the most important segments of the local economy. Vacationers come great distances to enjoy the fish, wildlife, and scenic resources of this area. The United States Forest Service has estimated that the recreational use of the National Forest lands within the California portion of West Walker River Basin was 293,000 visitor-days in 1955. It is anticipated that as travel conditions improve, thus reducing the travel time from major metropolitan centers, and the population of the State increases, the use of the recreational potential of the area will increase. Major services provided for the vacationers during the normal summer and fall hunting, fishing and camping seasons consist of furnishing lodging, supplies, pack animals, and guides. The motels along U.S. Highway 395 serve both vacationers and travelers.

Forest products make a minor contribution to the economy of the region, but not on a year-round basis. Principal products are lumber, fuel, and pine nuts. Lumber is produced principally from yellow pine located on National Forest lands. The sustained yield of the National Forest lands in the West Walker River Basin is estimated to be 500,000 board feet annually. This very small timber yield results in the lumber harvest being made at very infrequent intervals. The pinyon pine is used for fuel; it is also the species which produces the famous Nevada pine nuts. These nuts are harvested in the fall of the year for sale and distribution throughout most of Nevada and California.

The United States Marine Corps operates a "Cold Weather Training Center," which occupies about 30 acres at Pickel Meadows. The surrounding area is extensively used for maneuvers and survival training. Many of the permanent staff of the center reside in Antelope Valley at either the Marine Corps trailer village at Camp Antelope or in privately owned rental housing.

Hydrographic Units

The area of investigation was divided into the Antelope, Slinkard, Lost Canyon, Wheeler, and Pickel Hydrographic Units. These areas are shown on Plate 1, "Area of Investigation and Distribution of Precipitation and Runoff."

Antelope Hydrographic Unit contains approximately 86 square miles which includes all of the California portion of Antelope Valley and a portion of the surrounding hills. The average annual precipitation in this area is about 10 inches. The 11,000 acres of land irrigated in the area in 1956 lie at an elevation of approximately 5,100 feet. The West Walker River is the principal source of water for irrigation. Mill Creek and Slinkard Creek and return flow from irrigation in the Little Antelope Valley are used to supplement diversions from the river.

Antelope Valley is the principal agricultural area in the California portion of West Walker River Basin. Landowners in the valley are entitled to divert approximately 245 second-feet from the West Walker River for the irrigation of 15,300 acres under rights defined by Decree C-125 of the Federal District Court for Nevada (United States v. Walker Irrigation District, et al., Equity No. C-125, D. Nev. 1936). Of these rights, 221 second-feet belong to the Antelope Valley Mutual Water Company and 24 second-feet belong to individual landowners. The only storage right appurtenant to lands in the valley is the 1,200 acre-foot Poore Lake right. In addition to these rights, as provided for in Decree C-125, the local water users divert surplus water from the river. Diversions from the river are regulated by the Board of U.S. Water Commissioners, established pursuant to Decree C-125, and distributed to the individual water users by the Antelope Valley Mutual Water Company.

Slinkard Hydrographic Unit contains approximately 35 square miles, which encompasses the Slinkard Creek Watershed. The average annual precipitation in this area is about 11 inches. The 380 acres of land irrigated in 1956, which are principally in Slinkard Valley, are at an elevation of about 6,000 feet. Ground water and the two perennial streams, Slinkard Creek and Cedar Creek, a tributary of Slinkard Creek, provide the water for irrigation. Rights to the use of water from Slinkard Creek and tributaries have not been adjudicated.

The principal landowner in Slinkard Valley has constructed extensive works in order to utilize the limited water supply. Surface waters have been developed by construction of pipelines and spreader ditches. Pipelines divert water from springs or small creeks at the head of the alluvial fans and convey it across the porous soils at the head of the fan to the less pervious soils near the center of the valley. The spreader ditches intercept floodwaters flowing in the washes during the freshet season and after thundershowers and spread them over the alluvial fans. Ground water has been developed by the drilling of four wells. Two of the wells are used for stockwater; the other two produce approximately 1-1/2 to 2 second-feet for irrigation.

Lost Cannon Hydrographic Unit contains approximately 40 square miles, which includes Little Antelope Valley and the watersheds of Mill and Lost Cannon Creeks. The average annual precipitation in this area is about 17 inches. Approximately 1,000 acres of land, primarily in Little Antelope Valley at an elevation of about 5,500 feet, were irrigated in 1956 with water diverted from Lost Cannon, Mill, and Rodriquez Creeks. Adjudicated rights for the diversion of water from Lost Cannon and Mill Creeks total 12.3 second-feet. Rights to the use of water from Rodriquez Creek have not been adjudicated; however, this source is capable of supplying only about 1/2 second-foot during July and August.

Wheeler Hydrographic Unit includes approximately 112 square miles, encompassing the lands extending from the head of Antelope Valley upstream along the West Walker River to Pickel Damsite and the watershed of the Little Walker River. The 900 acres of land irrigated in 1956 lie at an elevation of approximately 7,000 feet. These lands are located in the watershed of the Little Walker River at Junction Meadows, Stockade Flat, Wheeler Bench, and Burcham Flat. Water supplies are secured from the local stream system. Adjudicated rights total 19.7 second-feet of natural flow and 350 acre-feet of storage for irrigation of 1,200 acres in this area. In addition to these rights, the Little Walker Cattlemen's Association is permitted by the Board of U.S. Water Commissioners to divert floodwaters for irrigation of National Forest and private lands not mentioned in Decree C-125. In addition to the irrigated lands, the service area contains 1,030 acres of natural meadow pasture.

Pickel Hydrographic Unit contains approximately 114 square miles, which lie in the watershed of the West Walker River above Pickel Meadow Damsite. The 560 acres of land irrigated in 1956 are located in Pickel and Leavitt Meadows, at an elevation of approximately 7,000 feet. There are many small mountain meadows in the upper portions of this service area in which natural high water tables prevail. Rights under Decree C-125 for irrigation in this area total 15.8 second-feet of natural flow.

The major reservoir sites located on the West Walker River, Roolane, Leavitt Meadow, and Pickel Meadow, are located in this unit. Construction of a reservoir at either of the latter two sites would inundate most of the irrigated land in this unit.

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CHAPTER II. WATER SUPPLY

Water used in the area of investigation is obtained from surface streams or ground water sources, practically all of which originates from precipitation on the watershed. The precipitation generally occurs as snow during the winter and as rainfall from thunderstorms in the summer and fall. Precipitation is greatest, as much as 70 inches annually, at the crest of the Sierra Nevada, decreasing rapidly to the semiarid eastern portion of the basin where it is only 6 to 8 inches annually.

Due to the rockiness and steep gradient of the basin, and the absence of any appreciable water storage facilities, the runoff from rainfall concentrates rapidly, sometimes creating floods. There is an extreme variation in the magnitude of rainfall runoff. Snowmelt usually begins in late spring and lasts until the snowpack is exhausted, generally in late summer or fall. Runoff from this source is more consistent and is utilized for irrigation during the summer. The average annual flow of the West Walker River near Coleville is 190,000 acre-feet.

Ground water occurs chiefly in the alluviated valleys within the basin. It may be possible to develop ground water for irrigation use in the Antelope and Slinkard

Valleys. Ground water development in the other valley areas will probably be limited to domestic or livestock use.

The quality of both the surface and free ground water is generally good to excellent, and is acceptable for most beneficial uses. However, scattered pockets of degradation do exist.

Precipitation

Precipitation in the West Walker River Basin results from a combination of frontal and orographic storms or from thermal convection. Frontal type storms occur along the line of discontinuity separating air masses of differing characteristics. Orographic type storms are induced by mountain barriers as air masses are forced over them. Thermal convection storms or thunderstorms are caused by localized inequalities in temperature at the boundary layer of the atmosphere.

During the winter, frontal type storms pass over the Sierra Nevada and are subjected to orographic effects. The precipitation resulting from these storms is deposited, usually as snow, on the Sierra Nevada and the Sweetwater Mountains. Occasionally, warm storms occurring largely in November or December, may cause precipitation in the form of rain even at high elevations. When such a storm causes intensive rainfall over an extended period a flood may result, particularly if the watershed has been covered with snow by preceding storms. Thunderstorms occur principally during the summer and fall and deposit intense precipitation in small areas. Distribution of precipitation from thunderstorms is very erratic, both as to time and location.

Precipitation records in this area are meager, there being only one long-term record in the California portion of the basin. The Shields Ranch weather station, located on Mill Creek in the southwest corner of Antelope Valley, operated from 1910 to 1946. Average precipitation at Shields Ranch for this period was 10.91 inches per season. From 1946 to 1955, the station was relocated several times within Antelope Valley. Since 1955, a station has been operated at Topaz Lake. A weather station was established at Sonora Junction near the junction of State Highway 108 and U.S. Highway 395 in 1959. The nearest other weather stations are Minden, Nevada; Wellington, Nevada; Bridgeport, California; Bode, California; Woodfords, California; and Markleeville, California; all located 20 to 40 miles from Antelope Valley.

The precipitation at Shields Ranch is detailed in Table 1.

Lines of equal mean seasonal precipitation over the area of investigation are shown on Plate 1, "Area of Investigation and Distribution of Precipitation and Runoff." This plate shows that precipitation is greatest at the crest of the Sierra Nevada, and decreases rapidly to the east. This is due to a combination of frontal and orographic storms which over-ride the crest and deposit snow on the eastern slope of the Sierra. In contrast, the eastern part of the basin, adjacent to Nevada, receives a substantial part of the precipitation from summer thunderstorms. The average annual precipitation here is very low, approximating 6 to 8 inches.

TABLE 1

PRECIPITATION AT SHIELDS RANCH*

1920-1955

Month	Inches		Average	
	Max.	Min.	Inches	Percent of annual
January	5.05	0	1.57	14
February	5.60	0.02	1.55	14
March	3.52	0	1.10	10
April	2.47	0	0.79	7
May	3.26	0	0.70	6
June	4.58	0	0.61	5
July	2.23	0	0.47	4
August	2.15	0	0.37	3
September	2.22	0	0.29	3
October	3.31	0	0.74	7
November	5.06	0	1.05	9
December	8.92	0	2.00	18
Total			11.19	100

*Precipitation forperiod 1945-55 estimated.

Runoff

Most of the water in the West Walker River originates on the high slopes of the Sierra Nevada during the late spring when the snows of winter melt. Peak flows for the year generally occur about the first of June, with lesser peaks of shorter duration caused by rain from November through March. Since the steep, rocky eastern slope of the Sierra Nevada has little capacity to retain rain or water from melting snow the fluctuation in streamflow is extreme. By contrast, flows of the Little Walker River and Lost Cannon Creek, which drain large masses of pervious material, are well sustained in the summer months. A greater portion of the flow of these streams is therefore usable for irrigation than is that of the main stem.

Intermittent records of streamflow in the West Walker River Basin in California have been kept since 1902. Since 1915, measurements have been kept continuously. Table 2 contains a compilation of the major streamflow records of the basin together with other pertinent data. Plate 2, "Historical Flow of the West Walker River at Head of Antelope Valley and Irrigation Demand Thereon in California," demonstrates the annual and monthly variation in flow at the head of Antelope Valley.

The period selected for study of streamflow was the 35 years from October 1, 1920, to September 30, 1955.

TABLE 2

SUMMARY OF HYDROGRAPHIC RECORDS AND ESTIMATED DATA

Location	Operating agency and period of 1/ record	2/ Average seasonal flow in acre-feet	Maximum 3/ seasonal flow		Minimum 4/ seasonal flow	
			in acre-feet	Per-cent of average	in acre-feet	Per cent of average
West Walker River at Leavitt Meadow	SPPC 1945-57 USGS-57	109,400	194,400	178	50,700	46
Intermediate Runoff		27,400	71,300	260	900	3
West Walker River above Little Walker		136,800	265,700	194	51,000	38
Little Walker River	USGS 1944-	33,300	67,300	202	9,100	27
West Walker River below East Fork near Coleville (Junction Gage)	USGS 1938-	170,100	333,000	196	60,700	28
Intermediate Runoff		20,100	39,600	197	7,200	28
West Walker River near Coleville (Antelope Gage)	USGS 1915-38 1957-60	190,200	372,600	196	67,900*	28
Intermediate Runoff		26,200	53,000	202	7,200	27
Antelope Valley Evaporation and Transpiration 5/		50,400				

TABLE 2 (continued)

SUMMARY OF HYDROGRAPHIC RECORDS AND ESTIMATED DATA

Location	Operating agency and period of 1/ record	2/ Average seasonal flow in acre-feet	Maximum 3/ seasonal flow: in acre-feet	Maximum 3/ seasonal flow: Per-cent of average	Minimum 4/ seasonal flow: in acre-acre-	Minimum 4/ seasonal flow: Per-cent of average
West Walker River at Hoye Bridge	USGS 1924-32 1957-	166,000	332,700	200	59,100	36
Other records used in part						
Topaz Lake storage	WRID 1931-					
Topaz Lake release	WRID 1940-					
West Walker River below Topaz diversion dam (field gage)	WRID 1940-					
West Walker River near Wellington	USGS 1917-24					
Saroni Canal near Wellington	USGS 1920-23					

1/ SPPC-Sierra Pacific Power Company
USGS- U.S. Geological Survey
WRID-Walker River Irrigation District
2/ Oct. 1, 1920, to Sept. 30, 1955
*Recorded

3/ Season Oct. 1, 1937, to Sept. 30, 1938
4/ Season Oct. 1, 1923 to Sept. 30, 1924
5/ Includes Topaz Res. Evaporation

This period approximates a long-term climatological cycle and includes some of the driest water years of record as well as some of the wettest.

A lack of complete records necessitated the reconstruction of historical streamflow at the various gaging stations. The available streamflow records were extended by computation and correlation. The key stations in the estimate of streamflow were the United States Geological Survey gaging stations, West Walker River below East Fork near Coleville (Junction Gage), operated from 1938 to present, and West Walker River near Coleville (Antelope Gage), operated from 1915 to 1938. These two stations, located above Antelope Valley, measure practically the entire flow of the river. However, the two gages are separated by 10 river miles and 64 square miles of watershed.

In order to complete the two records by estimating the intermediate runoff, the seasonal runoff for the period 1946 to 1955 at Leavitt Meadow, Little Walker, and Junction Gage was correlated with a watershed index based on the parameters of average watershed elevation, average precipitation on the watershed and area of watershed. From this correlation the average runoff of the intermediate watershed in terms of percent of flow at the Junction and Antelope Gages was estimated and used to extend the records at the Junction and Antelope Gages to a full 35 years. Flows of the West Walker River at Leavitt Meadow and the Little

Walker River near Bridgeport, were then correlated with the Junction Gage in order to extend the record at these two gages to 35 years.

The estimated seasonal flows were then prorated into individual monthly flows by a method which adjusts the monthly percentage of annual runoff at a base station to the runoff characteristics of the station for which the record is being extended.

The flow of West Walker River below the Topaz Intake Dam (Field Gage), the storage in Topaz Reservoir, and Topaz Reservoir releases have been recorded by the Walker River Irrigation District during the period 1945-55. However, the reliability of these records, particularly at high flows, is not sufficient to provide a basis for water supply estimates. It was, therefore, necessary to make a "water budget" study of the Antelope and Smith Valleys. This study considered (1) flow of the "West Walker River below East Fork Near Coleville" (Junction Gage) and local inflow as sources of water; (2) flows of the "West Walker River Near Hudson," diversions to Artesia Lake Basin, consumptive use of applied irrigation water and Topaz Reservoir evaporation as uses; and (3) ground water storage and Topaz Reservoir as regulatory storage. The study was conducted for a 12-year period, October 1, 1947, to September 30, 1959, for which concurrent records at Antelope Gage, Topaz Reservoir, and Hudson Gage were available. Values for local inflow, diversions, consumptive use, evaporation, ground water storage capacity and rate of percolation to and drainage from ground water were estimated by various means and then adjusted by successive approximation utilizing an IBM 650 digital computer. Computations for the 12-year period were repeated until monthly values of the flow of the West Walker River at Hudson could be duplicated with an average deviation of plus or minus 12 percent.

Ground Water

In general, usable ground water occurs only in the alluviated valleys of the area of investigation. While some ground water can be obtained from fractures, joints, and bedding planes in the volcanic, granitic, or metamorphic rocks, such sources are usually undependable and difficult to locate. For these reasons, it was concluded that these crystalline rocks are not an important source of ground water and are, therefore, not discussed in this report.

The glacial moraines in the area are limited in individual extent, largely above the water table, often dissected, and of variable permeability. It seems improbable that large volumes of water could be obtained from wells penetrating these deposits.

Antelope Valley is the only major ground water basin in the area. The other ground water basins are much smaller and, with the probable exception of Slinkard Valley, do not appear to be suitable for extensive ground water development. Probable location and extent of the ground water basins are shown on Plate 3, "Locations of Ground Water Storage Sites and Water Quality Sampling Points."

Table 3 presents estimates of the storage capacity in the ground water basins of the area. These estimates are based largely on the results of geologic reconnaissance; few water wells or other borings have been made. This is particularly true of the smaller ground water basins. The total ground water storage capacity in the storage interval between 10 and 100 feet below ground surface in the West Walker Basin in California is estimated to be in excess of 270,000 acre-feet.

Ground water storage capacity is the product of the area of the ground water basin, the depth interval considered, and the specific yield of the water-bearing deposits. Specific yield is defined as the ratio of the volume of water a saturated material will yield by gravity to its own volume.

In this investigation the nature of the alluvium in the ground water basins in which no well logs were available was postulated in the field from aerial photographs, then estimated specific yields and basin depths were assigned. The ground water storage figures derived in this manner are to be considered as approximate values only and are included only to show the approximate order of magnitude of such storage.

TABLE 3

ESTIMATED STORAGE CAPACITY OF GROUND WATER BASINS

Basin	Storage unit	Interval in feet	Area in acres	Specific yield 2/ in percent	Ground water storage in acre-feet
Antelope Valley	A 1/	10-100	8,800	15	118,800
	B 1/	10-100	11,000	5	49,500
Slinkard Valley		10-100	5,320	15	71,800
Little Antelope Valley		10-50	2,500	5	5,000
Pickel Meadows		10-50	1,435	5	2,870
Leavitt Meadows		10-50	480	5	960
Mill Canyon		10-100	800	15	10,800
Summit Meadow			495	This basin omitted because of probable extreme shallowness of fill.	
Lost Cannon Creek		10-100	775	15	10,500
Junction Meadows		10-50	1,035	5	2,100
Willow Flat		10-50	155	5	300

1/ Ground water storage Unit A includes upstream and central portions of alluvial fans and extensive deposits of coarse channel deposits. Unit B comprise fine-grained deposits of floodplains, the distal portions of large alluvial fans, and certain glacial deposits.

2/ Estimated from inspection of outcrops of the formation and from well logs where available.

Antelope Valley

Antelope Valley is bounded on all sides by faults along which movements of great magnitude have occurred. The valley has been depressed along these faults and is a typical basin-range graben or down-dropped block. The valley fill consists of alluvial fan, floodplain, and river channel deposits. There is indirect evidence that there are also some interbedded lake deposits, but none of these beds were observed in the field.

Ground water in Antelope Valley occurs in unconfined and artesian zones. Depths to ground water in the upper zone varies from 160 feet in the southeastern portion of Antelope Valley to less than 2 feet in many places in the center of the valley.

Artesian areas are known to exist in the center of the valley, although their depth and areal extent has not been determined. Evidence of such areas is given by artesian wells, some of which are more than 90 feet deep. One artesian well, drilled near Topaz around 1910, gave a yield sufficient to supply the entire community at that time. The same well was still supplying two family residences nearly a half century later.

The water secured from artesian wells in the area has relatively high concentrations of boron, fluorides, and arsenic. There are, however, small areas along the east side of the valley which do not show the poor water quality characteristics of the main artesian zones. Except for the mineral seeps adjacent to Topaz Lane, two miles east of Highway 395 in Antelope Valley, the springs at the toe of the east side alluvial apron appear to result from irrigation water being applied on the alluvial apron. The impervious layers in the apron are probably discontinuous, allowing water to percolate between and below them and then flow to the toe of the alluvial apron. As an example of the relationship of irrigation to the artesian pressure in this area, a relatively shallow well located at the East Camp Ranch House on Topaz Lane two miles east of Highway 395, flows under artesian pressure only during the season when the fields above the well are irrigated with surface water.

The total ground water storage capacity in Antelope Valley is estimated to be about 170,000 acre-feet in the storage interval between 10 and 100 feet depth in the ground water basin. Bailing tests on existing shallow wells on the Mill Creek fan in the southwest corner of the valley indicate a low yield of water in relation to drawdown. Thus, it seems unlikely that large capacity irrigation wells could be developed in this part of the valley without drilling to great depths in order to intercept a large thickness of aquifer. Pumping a deep water well in this type aquifer would produce a large drawdown and would require a high pump lift.

Hydrologic studies indicate that about 29,000 acre-feet of the Antelope Valley ground water storage capacity is free draining. It apparently drains continuously in proportion to the amount of water in storage and is recharged by deep percolation from irrigation and runoff from the surrounding watershed. It may be possible to develop large irrigation wells in the floodplain area by intercepting and pumping from old, buried stream channels. The transmissibility of these coarse deposits of sand and gravel should be sufficient to supply adequate amounts of water to irrigation wells. Inability to predict the location of such channel deposits introduces an element of risk into drilling an irrigation well.

Slinkard Valley

Slinkard Valley lies about two miles to the west of Antelope Valley and is separated from it by a faulted ridge of bedrock. A complex fault, along which this valley has been depressed, lies at the western margin of the valley. The area of Slinkard Valley is a little more than eight square miles.

The alluvial fill of this valley consists almost entirely of steep alluvial fan deposits. Locally these sediments have been eroded by Slinkard Creek and backfilled with a ribbon of fine-grained deposits. However, the deposits of Slinkard Creek account for a very small portion of the bulk of the valley fill.

A water well drilled near the center of the valley reached "hard rock" at a depth of 577 feet. The log of this well shows considerable amounts of clay mixed with the sands and gravels of the alluvial fans and as interbedded clay layers.

The most extensive ground water development for irrigation in the West Walker River Basin is in Slinkard Valley. Deep irrigation wells presently provide a dependable source of supplemental irrigation water. The ground water storage capacity between depths of 10 and 100 feet is estimated to be about 72,000 acre-feet.

Little Antelope Valley

Little Antelope Valley is separated from the southwestern portion of Antelope Valley by a narrow ridge of uplifted metamorphic rock. The valley fill consists largely of alluvial fan deposits with some glacial debris in the upper end of the valley. The depth of this material appears to be limited, as volcanic deposits are exposed in the incised stream channel at the northern end of the valley and along the road which leaves the valley at the south. The southeasterly portion of the valley is composed of a dissected deposit of either glacial or alluvial fan origin.

In view of the widespread occurrence of the fine-grained fan deposits and the possible existence of glacial material in the upper portion of the valley, it is believed that the specific yield of the water-bearing strata is relatively low. Because of this and the apparently shallow depth of fill in the valley, only 5,000 acre-feet of storage is conservatively considered to be available between depths of 10 and 50 feet.

It is improbable that irrigation wells with large discharges can be developed. However, the basin is suitable for the production of small quantities of ground water for domestic or livestock use.

Minor Basins

A number of small ground water basins exist along the West Walker River and Mill Creek above Antelope Valley. The majority of these are mountain meadows. The valley fill consists of floodplain, lake and glacial deposits. Two of the ground water basins in the Mill Creek watershed, Mill Canyon and Lost Cannon Creek Basins, are largely alluvial fan deposits. The area, estimated specific yield, and estimated storage capacity of these basins are summarized in Table 3. The locations of these basins are shown on Plate 3.

Water Quality

During 1955 and 1956 sampling of the surface and ground water supplies of the West Walker River Basin was undertaken in order to determine the existing water quality conditions in the basin and to determine whether there were any water quality problems which would influence the development of the water resources of the basin. The sampling locations are indicated on Plate 3, and the results of a mineral analysis are presented in Tables 4 and 5.

Water Quality Standards

The standards and criteria used by the Department of Water Resources in determining the suitability of water for domestic and municipal water supply and irrigation purposes in this investigation were as follows.

The following classification of waters by degrees of hardness, suggested by the United States Geological Survey, was used for domestic and municipal water.

Class	Range of hardness, expressed as calcium carbonate ($Ca\ CO_3$) in ppm
1	0 - 55 soft
2	56 - 100 slightly hard
3	101 - 200 moderately hard
4	201 - 500 very hard

Waters of Classes 1 and 2 generally require no softening, while those of Class 3 and 4 ordinarily require softening to a varying degree, depending on the uses to which they are put.

The suitability of water for irrigation was determined by the Department of Water Resources by use of criteria included in the publication, "Qualitative

Classification of Irrigation Waters," by Dr. L. D. Doneen, University of California, Davis. Irrigation waters were divided into three broad groups:

Class 1. EXCELLENT TO GOOD - Regarded as safe and suitable for most plants under any condition of soil or climate.

Class 2. GOOD TO INJURIOUS - Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

Class 3. INJURIOUS TO UNSATISFACTORY - Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Quality of Surface Water

Runoff from the upper watershed of the West Walker River is soft to slightly hard and of excellent quality.

The principal inflow to the West Walker River in the upper drainage area is from the more mineralized Little Walker River, which enters the West Walker River approximately 10 miles south of Antelope Valley. The major source of the mineral content observed in the Little Walker River is Hot Creek, which in turn derives the greater portion of its supply from numerous highly mineralized hot springs, including Fales Hot Springs. The water of the Little Walker River below its junction with Hot Creek is a soft, predominately sodium bicarbonate type, with concentrations of sodium and boron closely approaching Class 2 irrigation water. The quality of water in the Little Walker River above its junction with Hot Creek, appears to more generally approximate the quality of the West Walker River in its upper reaches. The small flows which originate in Hot Creek show a high content of sodium bicarbonate with excessive concentrations of fluoride and boron. In addition, the waters of Hot Creek show concentrations of sulfate, chloride and total dissolved solids considerably in excess of the mineral concentrations found in all the other surface streams in the West Walker drainage area.

The West Walker River, below its junction with Little Walker River, generally reflects the quality of the main stream in its upper reaches. This is due principally to the greater flow entering from the upper West Walker River. Analyses have been based on samples taken during low or average magnitudes of flow; direct comparisons of quality in these two streams at high flow conditions are not available.

Other streams which contribute to the Antelope Valley water supply are: Mill, Lost Cannon, Rodriquez, and Slinkard Creeks. These streams are all of excellent quality and are generally suitable for most beneficial uses. Flows are similar in quality to waters of the upper reaches of West Walker River.

The major part of the irrigation return flows, local drainage and seepage enters the Topaz Intake Canal just below East Slough. The flows at this location contained significantly high concentrations of fluoride and boron toward the latter part of the 1955 irrigation season. Inflow to Topaz Lake was of the sodium bicarbonate type and contained greater concentrations of chlorides than did waters in the upper reaches of the West Walker River. Evidence of a boron concentration in excess of that in the upper West Walker River was also observed in the irrigation diversions to the Swager and Rickey ditches.

Releases from Topaz Lake for irrigation in Nevada are a soft calcium-bicarbonate type water of excellent quality. The concentrations of fluoride and boron observed in the inflow to the lake during August and November 1955, were not evidenced in Topaz Lake releases. This is probably due primarily to dilution of irrigation return flow in the lake by flows of better quality water entering the lake during the spring snowmelt period.

It should be pointed out that all of the analyses were run on samples collected in August through November 1954, 1955, and 1956. These periods of low water supply represent periods of below average water quality. Better quality water would probably be found in the surface streams during other periods of the year when streamflow is greater. Other than the few instances of inferior quality heretofore mentioned, surface waters in the West Walker River drainage basin are generally suitable for the beneficial uses common to the area.

Quality of Ground Water

Excellent quality ground water of slightly to moderately hard calcium-bicarbonate nature were observed in the Little Antelope and Slinkard Valleys. The quality of ground water generally reflected the quality of the streams recharging these minor basins.

Wells in Antelope Valley which draw water from the free ground water zone are of good to excellent quality and appear suitable for all domestic and irrigation uses.

Two flowing wells, located to the east of the West Walker River and adjacent to Topaz Lane in Antelope Valley yielded a sodium bicarbonate-chloride type water with a high percentage of sodium and with excessive concentrations of fluoride and boron. A mineral hot springs, situated between Topaz and Topaz Lake Diversion Dam in immediate proximity to the east side of the river, appears to derive its water supply from the same zone as that of the above-mentioned artesian wells. This poor quality water possibly originates in a series of faults running north and south along the eastern and western fringes of the valley. A domestic well 125 feet in depth, located approximately 2 miles southeast of Topaz at Bellview Ranch, yielded a sodium-bicarbonate type water with a high percentage of sodium and with significant amounts of fluoride and boron, though not nearly in such critical concentrations as the aforesaid flowing wells and hot springs to the north. It is possible that water from this latter well is a mixture of good quality free ground water and the underlying highly mineralized water.

The previously mentioned excessive percentages of sodium and concentrations of boron in the underlying pressure zone make this a questionable source of irrigation water supply. However, this water might be made more usable by mixing it with available good quality water from the upper zone or with surface water diversions. Fluoride content considerably in excess of the mandatory limiting concentrations of 1.5 parts per million (ppm) also makes water from the pressure zone generally unsuitable for domestic supply, although it 1956 it was being used for domestic and stock watering purposes. In addition, an excessive concentration of arsenic, toxic to humans and animals, was noted in the mineral hot springs located at the lower end of the valley. These mineral hot springs showed an arsenic content of 0.18 ppm as compared with the mandatory limit of 0.05 ppm. Water originating in the pressure aquifer also contains a concentration of arsenic in excess of this limit. This is substantiated by analyses from a flowing well (9N/23E-30C1) located one and one-half miles southeast of the mineral hot springs, which shows an arsenic concentration of 0.12 ppm and from the East Camp Ranch well (9N/23E-20P1) located about one mile farther east containing 0.06 ppm. From this standpoint alone, the water supply should not be considered satisfactory for domestic or stock watering uses.

The ground water sampled in the West Walker River Basin ranged from soft to moderately hard. Only that from the Fairfield irrigation well in Slinkard Valley exhibited hardness in excess of 150 ppm.

To summarize, free ground water in Antelope, Little Antelope, and Slinkard Valleys is generally of good quality and suitable for present and future beneficial uses in the area. Ground water originating in the pressure zone of Antelope Valley should be considered as an unsatisfactory source of water supply for both domestic and irrigation uses due to excessive concentrations of arsenic, fluoride and boron, and a high percentage of sodium.

TABLE 4

MINERAL ANALYSES OF SURFACE WATER[a]

WEST WALKER RIVER DRAINAGE BASIN

Source	Location number M.D.B.&M.	Date sampled	Discharge in cfs	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents[c]	Total dissolved solids in ppm[b]	Per cent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm
							Mineral constituents in parts per million / equivalents per million																
West Walker River	6N/23E- 9J1S	8/30/55	53	67	144	8.2	18 0.90	3.3 0.27	6.0 0.26	1.2 0.03	0 0.00	79 1.30	10 0.21	0.3 0.01	0.0 0.00	0.2 0.01	0.07	11		89	18	59	0
Little Walker River	6N/23E- 9J2S	8/30/55	--	67	203	8.5	11 0.55	2.5 0.21	27 1.17	2.9 0.07	4 0.13	90 1.48	16 0.33	2.4 0.07	0.5 0.01	0.2 0.01	0.42	18		129	59	38	0
Hot Creek	6N/23E-27E1S	8/ 9/56	1.5[d]	51	1160	8.2	29 1.45	9.7 0.80	229 9.96	20 0.51	0 0.00	510 8.36	93 1.94	76 2.14	1.0 0.02	1.8 0.09	3.3	63	Fe (Total) 0.20	777	78	112	0
Little Walker River	6N/23E-28H1S	8/ 9/56	180[d]	45	56.2	7.2	7.4 0.37	1.3 0.11	2.0 0.09	0.7 0.02	0 0.00	33 0.54	2.7 0.06	0.0 0.00	0.3 0.01	0.1 0.01	0.00	11	Fe (Total) 0.09	42	15	24	0
Mill Creek	7N/23E- 6H1S	8/ 4/55	0.7	--	264	7.6	37 1.85	4.9 0.40	10 0.44	3.2 0.08	0 0.00	162 2.66	4.8 0.10	0.8 0.02	0.2 0.00	0.2 0.01	0.06	43		184	16	112	0
Little Antelope Valley Outlet Creek	8N/23E-18N1S	8/ 4/55	0.4	--	309	7.8	37 1.85	6.4 0.53	22 0.96	1.4 0.04	0 0.00	196 3.21	6.3 0.13	0.9 0.02	0.4 0.01	0.6 0.03	0.06	43		215	28	119	0
West Walker River	8N/23E-28B1S	8/ 4/55	100	--	144	7.6	9.1 0.45	2.3 0.19	9.5 0.41	1.4 0.04	0 0.00	56 0.92	5.9 0.12	2.4 0.07	0.2 0.00	0.2 0.01	0.10	16		75	38	32	0
Lost Cannon Creek	8N/23E-31J1S	8/ 4/55	5.4	--	59.5	7.2	6.5 0.32	0.4 0.04	5.4 0.24	1.2 0.03	0 0.00	30 0.49	5.8 0.12	0.3 0.01	0.1 0.00	0.2 0.01	0.00	23		58	38	18	0
West Walker River	8N/23E-33B1S	8/ 3/54	20[d]	--	118	6.9	11 0.55	1.8 0.15	9.5 0.41	1.5 0.04	0 0.00	60 0.98	5.9 0.12	1.9 0.05	0.1 0.00	0.2 0.01	0.12	16		78	36	35	0
Slinkard Creek	9N/22E-10F1S	8/ 4/55	1.3	--	312	8.2	35 1.75	13 1.08	12 0.52	5.0 0.13	0 0.00	206 3.38	5.8 0.12	0.2 0.01	0.1 0.00	0.2 0.01	0.04	48		220	15	141	0
East Slough near Topaz Intake Canal	9N/22E-12R1S	8/ 4/55	6[d]	--	312	7.6	28 1.40	5.7 0.47	31 1.35	4.9 0.12	0 0.00	175 2.87	10 0.21	6.4 0.18	0.6 0.01	1.0 0.05	0.47	38		212	40	93	0
Topaz Intake Canal	9N/22E-12R2S	8/ 4/55	38	--	281	7.7	23 1.15	5.6 0.46	29 1.26	3.9 0.10	0 0.00	143 2.34	12 0.25	12 0.34	0.2 0.00	1.0 0.05	0.58	31		188	42	80	0
		11/ 3/55	56	--	255	8.1	22 1.10	4.5 0.37	24 1.04	3.0 0.08	0 0.00	116 1.90	11 0.23	14 0.40	0.1 0.00	1.1 0.06	0.62	26	Fe 0.03; Al 0.05; Mn 0.00; Cr 0.00; Cu 0.02; Pb 0.00; Zn 0.00; As 0.01; Mo 0.00	163	40	74	0
Swager & Rickey Ditches at Diversion Point	9N/22E-36B1S	8/ 9/55	--	--	207	7.8	20 1.00	4.9 0.40	15 0.65	2.8 0.07	0 0.00	102 1.67	8.5 0.18	11 0.31	0.1 0.00	0.3 0.02	0.34	25		138	31	70	0
East Slough at Topaz Lane	9N/23E-19P1S	11/ 2/55	12[d]	52	290									6.4 0.18			0.18						
Ditch at East Topaz Lane	9N/23E-20N1S	11/ 2/55	4[d]	53	400									9.0 0.25			0.41						
Ditch at West Topaz Lane	9N/23E-30C1S	11/ 2/55	1.5[d]	52	263									14 0.40			0.11						
East Slough at Church Lane	9N/23E-31K1S	11/ 3/55	12[d]	--	227									5.0 0.14			0.10						

a - Analyses by United States Geological Survey, Quality of Water Branch, Sacramento Laboratory.
b - Calculated from analyzed constituents.
c - Iron (Fe), Aluminum (Al), Manganese (Mn), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn), Arsenic (As), and Molybdenum (Mo) not analyzed for except as shown.
d - Estimated.

TABLE 4 (Continued)
MINERAL ANALYSES OF SURFACE WATER[a]
WEST WALKER RIVER DRAINAGE BASIN

Sheet 2 of 2

Source	Location number M.D.B.&M.	Date sampled	Discharge in cfs	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents[c]	Total dissolved solids in ppm[b]	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm
							Mineral constituents in parts per million / equivalents per million																
Hot Water Ditch at Church Lane	9N/23E-32Q1S	11/ 2/55	--	46	156									1.6 0.04			0.08						
Topaz Lake Outlet Canal	10N/22E-27P1S	9/20/56	250[d]	63	137	7.6	13 0.65	3.8 0.31	10 0.44	1.7 0.04	0 0.00	78 1.28	3.5 0.07	3.8 0.11	0.6 0.01	0.3 0.02	0.10	12	Fe 0.01	87	30	48	0
Topaz Lake near Outlet	10N/22E-33A1S	8/ 4/55	--	--	158	7.3	14 0.70	3.3 0.27	12 0.52	2.0 0.05	0 0.00	80 1.31	6.3 0.13	4.3 0.12	0.9 0.02	0.4 0.02	0.16	8.2		91	34	48	0

a - Analyses by United Statee Geological Survey, Quality of Water Branch, Sacrsmsnto Laboratory.
b - Calculated from analyzed constituents.
c - Iron (Fe), Aluminum (Al), Manganese (Mn), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn), Arsenic (Ae), and Molybdenum (Mo) not analyzed for except ae shown.
d - Estimated.

TABLE 5

MINERAL ANALYSES OF GROUND WATER[a]
WEST WALKER RIVER DRAINAGE BASIN

Sheet 1 of 2

Source	Well number M.D.B.&M.	Date sampled	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents[c]	Total[b] dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks
						Mineral constituents in parts per million / equivalents per million																	
Starr Domestic Spring Leavitt Meadows	6N/22E-34E1	9/28/56	--	162	--	22 / 1.10	3.2 / 0.26	7.7 / 0.33	1.7 / 0.04	0 / 0.00	107 / 1.75	1.5 / 0.03	0.8 / 0.02	0.1 / 0.00	0.0 / 0.00	0.00	18	As 0.00	108	19	68	0	
Fales Hot Springs	6N/23E-24K1	11/ 3/55	140	2570	7.0	45 / 2.25	7.2 / 0.59	587 / 25.53	41 / 1.05	0 / 0.00	1110 / 18.19	260 / 5.41	158 / 4.46	0.1 / 0.00	4.4 / 0.23	15	116	Fe 0.22; Al 0.09; Mn 0.09; Cr 0.00; Cu 0.02; Pb 0.00; Zn 0.01; As 1.1; Mo 0.00	1780	87	142	0	
Fritz Middleman Domestic Spring	8N/23E- 7G1	11/ 3/55	--	128	6.8	13 / 0.65	2.7 / 0.22	7.8 / 0.34	2.3 / 0.06	0 / 0.00	58 / 0.95	9.4 / 0.20	3.2 / 0.09	0.7 / 0.01	0.3 / 0.02	0.24	23		92	27	44	0	
Dave E. Radley Domestic Well	8N/23E-16P1	8/30/55	--	359	7.5	34 / 1.70	11 / 0.93	26 / 1.13	4.3 / 0.11	0 / 0.00	224 / 3.67	6.7 / 0.14	3.0 / 0.08	6.0 / 0.10	0.1 / 0.01	0.10	29		230	29	131	0	Depth - 253 ft Perforations - 222 to 252 ft
Rosachi Domestic Well	8N/23E-19E1	8/30/55	--	229	6.7	24 / 1.20	5.8 / 0.47	14 / 0.61	5.1 / 0.13	0 / 0.00	142 / 2.33	2.2 / 0.05	0.3 / 0.01	2.1 / 0.03	0.2 / 0.01	0.11	43		167	25	84	0	
Ike's Sporting Goods Store Domestic Well	8N/23E-29C1	8/30/55	--	146	6.7	15 / 0.75	4.9 / 0.40	8.0 / 0.35	2.0 / 0.05	0 / 0.00	84 / 1.38	4.2 / 0.09	1.6 / 0.04	1.6 / 0.03	0.2 / 0.01	0.05	27		106	22	57	0	Depth - 108 ft Perforations - 80 to 105 ft
George Roberts Domestic Well	9N/22E- 1N1	8/10/54	--	294	8.4	27 / 1.35	15 / 1.25	10 / 0.44	3.9 / 0.10	6 / 0.20	156 / 2.56	5.4 / 0.11	4.5 / 0.13	10 / 0.16	0.0 / 0.00	0.24	52		211	14	130	0	Depth - 60 ft
		8/30/55	53	263	7.0	27 / 1.35	11 / 0.87	9.6 / 0.42	3.6 / 0.09	0 / 0.00	153 / 2.51	7.7 / 0.16	5.4 / 0.15	1.1 / 0.02	0.1 / 0.01	0.19	52		193	15	111	0	
Hot Springs Near Topaz	9N/22E-13H1	10/12/55		570	8.7	6.7 / 0.33	0.4 / 0.03	114 / 4.96	2.8 / 0.07	9 / 0.30	83 / 1.36	53 / 1.10	77 / 2.17	0.1 / 0.00	7.0 / 0.37	2.7	52	Fe 0.00; Al 0.03; Mn 0.00; Cr 0.00; Cu 0.02; Pb 0.00; Zn 0.01; As 0.18; Mo 0.00	366	92	18	0	
Fairfield Irrigation Well	9N/22E-20J1	8/30/55	52	381	7.5	50 / 2.50	14 / 1.16	9.8 / 0.43	2.1 / 0.05	0 / 0.00	224 / 3.67	25 / 0.52	1.3 / 0.04	0.9 / 0.02	0.1 / 0.01	0.08	35		248	10	183	0	
Kinzy Domestic Well	9N/22E-24M1	11/ 2/55	--	206	7.5	18 / 0.90	5.8 / 0.47	16 / 0.70	2.3 / 0.06	0 / 0.00	103 / 1.69	13 / 0.27	3.8 / 0.11	2.7 / 0.04	0.4 / 0.02	0.00	33		146	33	69	0	Depth - 50 ft
Brooks Park Artesian, Domestic and Irrigation Well	9N/23E-20P1	8/ 8/56	--	298	8.2	39 / 1.95	7.5 / 0.62	18 / 0.78	1.5 / 0.04	0 / 0.00	180 / 2.95	13 / 0.27	4.0 / 0.11	1.7 / 0.03	0.5 / 0.03	0.22	47	Fe 0.00; Al 0.16; Mn 0.00; Cr 0.00; Cu 0.01; Pb 0.00; Zn 0.00; As 0.06	221	23	128	0	Depth - 60 ft
Frank Chichester Artesian Stock Well	9N/23E-29D1	8/30/55	62	497	7.9	15 / 0.75	0.6 / 0.05	85 / 3.70	3.5 / 0.09	0 / 0.00	103 / 1.69	32 / 0.67	74 / 2.09	0.7 / 0.01	6.0 / 0.32	2.0	58		328	81	40	0	Depth - 95 ft
A. Sciarani Artesian Domestic Well	9N/23E-30C1	8/30/55	--	546	8.5	0.9 / 0.04	1.5 / 0.12	106 / 4.61	1.8 / 0.05	4 / 0.13	48 / 0.79	47 / 0.98	92 / 2.59	0.0 / 0.00	10 / 0.53	2.1	60		349	96	1	0	Depth - 100 ft
		9/29/56	--	539	7.1													Fe 0.02; Al 0.05; Mn 0.00; Cr 0.00; Cu 0.03; Pb 0.00; Zn 0.02; As 0.12					

a - Analyses by United States Geological Survey, Quality of Water Branch, Sacramento Laboratory.
b - Calculated from analyzed constituents.
c - Iron (Fe), Aluminum (Al), Manganese (Mn), Chromium (Cr), Copper (Cu), Lead (Pb), Zinc (Zn), Arsenic (As), and Molybdenum (Mo) not analyzed for except as shown.

TABLE 5 (Continued)
MINERAL ANALYSES OF GROUND WATER[a]
WEST WALKER RIVER DRAINAGE BASIN

Sheet 2 of 2

Source	Well number M.D.B.&M.	Date sampled	Temp in °F	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents[c]	Total[b] dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks
						Mineral constituents in parts per million / equivalents per million																	
Ray Charleboise Domestic Well	9N/23E-30M1	8/30/55	59	157	8.0	15 / 0.75	2.8 / 0.23	13 / 0.56	1.8 / 0.05	0 / 0.00	92 / 1.51	4.0 / 0.08	1.4 / 0.04	0.7 / 0.01	0.2 / 0.01	0.40	29		113	36	49	0	Depth - 50 ft Cased to 15 ft
L. Ashurst Domestic Well	9N/23E-31R1	11/ 3/55	--	190	7.7	15 / 0.75	4.3 / 0.35	18 / 0.78	2.6 / 0.07	0 / 0.00	103 / 1.69	5.4 / 0.11	2.6 / 0.07	1.8 / 0.03	0.6 / 0.03	0.04	34		135	40	55	0	
Bellview Ranch Domestic Well	9N/23E-32A1	8/30/55	62	358	8.1	16 / 0.80	4.6 / 0.38	60 / 2.61	3.1 / 0.08	0 / 0.00	215 / 3.52	8.7 / 0.18	3.1 / 0.09	3.6 / 0.06	2.4 / 0.13	0.52	30		238	68	59	0	Depth - 125 ft

a - Analyses by United States Geological Survey, Quality of Water Branch, Sacramento Laboratory.
b - Calculated from analyzed constituents.
c - Iron (Fe), Aluminum (Al), Manganese (Mn), Chromium (Cr), Copper (Cr), (Cu), Lead (Pb), Zinc (Zn), Arsenic (As), and Molybdenum (Mo) not analyzed for except as shown.

CHAPTER III. PRESENT WATER SUPPLY DEVELOPMENT AND WATER RIGHTS

Water use in the West Walker River Basin began about 1859 when pioneers first settled in the Antelope Valley. Use of water, principally for agriculture, developed rapidly thereafter until about the year 1900 when the flow of the West Walker became insufficient to meet the demand. As the lack of water became more vexing, recourse was made, beginning in 1902, to the courts, which struggled with the problem of insufficient supply during the next 50 years. Most of the rights to divert and store streamflow for irrigation are now regulated under Decree C-125 of the Federal District Court of Nevada, United States v. Walker River Irrigation District, et al, Equity No. C-125 (1936).

The water supply for irrigation and stock use is primarily obtained by diverting from the natural flow of the streams in the basin. Although diversions are regulated by a federal watermaster under Decree C-125, streamflow is often insufficient during the latter part of the irrigation season to supply the demands in Antelope Valley.

Water for domestic needs is mostly obtained from springs and wells. Surface water is used for domestic purposes only in campgrounds and in a small portion of the Antelope Valley. Ground water supplies appear to be adequate to meet present domestic use except in the town of Walker.

The surface supply utilized for domestic needs in the Antelope Valley is often inadequate during periods of low flow in July and August.

Domestic Water Supply

The principal source of water for domestic purposes is ground water. Springs are the preferred source of this water. Wells have been constructed wherever physical conditions and economic limitations permit. Use of surface water for domestic purposes is limited to the campgrounds in recreational areas, and to a group of small landowners in Antelope Valley served by the Lone Company Ditch of the Antelope Valley Mutual Water Company. Except for the town of Walker and the Lone Company Ditch water users, present domestic supplies are adequate.

The town of Walker is located in the southwest corner of Antelope Valley on the alluvial fan of Mill Creek. Wells in this area drilled during the good water-supply years of 1951 through 1953, had to be increased in depth during the two subnormal water-supply years of 1954 and 1955. The drop in the water table was probably caused by the combination of increased pumping and drought conditions. Although water levels recovered in 1956, the possibility remains that the water demand of the community exceeds the supply from this source.

The majority of landowners receiving irrigation water from the Lone Company Ditch in Antelope Valley also obtain their domestic supplies from the ditch. The ditch is a branch of Main Canal, which diverts water from the West Walker River at the head of Antelope Valley. In late July or early August, the share of the available water supply to which these water users are entitled becomes insufficient to meet conveyance losses. During such periods the Antelope Valley Mutual Water Company "water man" attempts to maintain enough flow in the ditch to meet domestic requirements. However, the lower end of the ditch is frequently dry because of difficulties in regulating diversions.

The residents of this area occupy parcels of 10 to 60 acres which are farmed to provide a small income to supplement wages earned by other employment. Wells that have been drilled in this area range from 100 to 265 feet in depth. The static water level in these wells ranges in depth from 80 to 170 feet below ground surface. Ground water development under these conditions has proven to be beyond the financial ability of most of these people.

Agricultural Water Supply

Irrigation and stock watering is largely supplied by diversion from the natural flow of the local stream system. The typical irrigation system consists of a diversion dam in the stream, a lockable headgate, a Parshall flume for measuring diversions, unlined ditches or canals to convey the water to the ranch, and turnout boxes to deliver water to the fields. Methods of irrigation used to apply water to the land consist of wild flooding, border check, and corrugation methods. Wild flooding is the most common method used in the valley. Border checks and corrugations are used largely on the hay lands located on the alluvial aprons at the sides of the valley. Border checks are used on lands which have been leveled and corrugations are used on nearly level lands which may have been graded but have not been brought to exact grade by the use of a land plane. Farm laterals are built on extremely flat grades and the water is spread on the fields by checking up the laterals and allowing the water to spill out over the edge of the ditch.

Diversions from the stream system are regulated by a watermaster acting under the direction of the Board of U.S. Water Commissioners, who administer Decree C-125 of the Federal District Court of Nevada. Decree C-125 was entered in the case of United States v. Walker River Irrigation District on April 14, 1936. Water rights of lands in the area of investigation, defined in Decree C-125 total 292 second-feet of natural-flow rights and 1,550 acre-feet of storage rights. Duty of water as set in the decree is 1.6 second-feet per 100 acres, which is equivalent to 0.98 acre-feet per acre for a 31 day month. The Board of U.S.

Water Commissioners does not exercise jurisdiction over Slinkard Creek as it is not included in Decree C-125. Rights to the use of Slinkard Creek to supplement water diverted from the West Walker River are exercised by ranchers located at the mouth of Slinkard Creek in Antelope Valley. During the irrigation season, flow of the creek partially offsets the conveyance losses suffered in the five miles of ditch between the West Walker River and these ranches.

Water Rights

Settlement of Antelope Valley began about 1859 when pioneer stock men began moving into the valley with herds of cattle. Priorities attributed to appropriative rights adjudicated by the federal courts indicate that irrigation started in Antelope Valley about 1862. Irrigated agriculture developed very rapidly in the years thereafter. This development, stimulated by the Nevada silver boom of the 1860's and 1870's, continued until about 1900 when the natural flow of the stream became insufficient to meet the ever increasing diversions.

In 1902 Miller and Lux, owners of land located principally in Nevada, initiated a suit against Thomas B. Rickey, et al, for the purpose of adjudicating the rights to the use of the waters of the Walker River. Rickey Land and Cattle Company, a successor to Thomas B. Rickey, later began two actions against Miller and Lux in a state court in California. In 1906, Miller and Lux filed suit to restrain the California proceedings. The Rickey interests challenged the jurisdiction of the Nevada Federal District Court to decide the right to property situated in California. This latter case was carried to the Supreme Court where it was decided that the federal court had concurrent jurisdiction with the state court with respect to the controversy, and under principles of comity, having first acquired jurisdiction in the case, should proceed to determine the issues. (Rickey Land and Cattle Company v. Miller & Lux, 218 U.S. 258 /1910/.)

During the Nevada gold-mining boom of the early 1900's, Thomas B. Rickey was also involved in mining and banking activities. He suffered failure in the panic of 1907. The ranching properties were then sold to the Antelope Valley Land and Cattle Company. Agreements between the Antelope Valley Land and Cattle Company, Miller and Lux (succeeded by Pacific Livestock Company) and the small individual water users in the basin were negotiated. These agreements, which are recited in the decree, provided the basis for the stipulated judgment entered in 1919 as Decree 731 of the Federal District Court for Nevada. The decree was entered as the case of Pacific Livestock Company v. Rickey, et al, Equity No. 731.

Subsequent to the foregoing litigation, the Walker River Irrigation District in Nevada was formed and Topaz Lake Reservoir constructed. Storage in Topaz Lake Reservoir began January 30, 1922. The reservoir lies in a small fault-block basin separated from the West Walker River by the alluvial fan of Slinkard Creek. Water is brought into the reservoir through a 1,000 second-foot-capacity intake canal and is released through an outlet tunnel and canal nearly 2-1/2 miles in length which joins the West Walker River about 3 miles upstream from Hoye Bridge, Nevada. The original capacity of the reservoir was 45,000 acre-feet. In 1937, the irrigation district raised the water level of the lake by construction of a levee at the south end. According to U.S. Geological Survey Water Supply Papers, the present storage is 59,440 acre-feet.

In 1924, the United States, on behalf of the Walker River Indian Reservation at Walker Lake in Nevada, initiated an action to determine the rights of the upstream water users. This comprehensive adjudication entitled the "United States v. Walker River Irrigation District, et al," was carried to the Circuit Court of Appeals, Ninth Circuit (104 Fed 2d 334 [1939]). In order to conclude the litigation, the defendants agreed to a stipulation in Decree C-125 which granted the Walker River Indian Reservation a right of 1859 priority for irrigation of 2,100 acres.

During this latter period of litigation the lands of the Antelope Valley Land and Cattle Company were subdivided and sold to a number of individual ranchers. Water rights adjudicated in Decree 731 were transferred to the Antelope Valley Mutual Water Company. One share of water company stock was distributed with each acre of land sold. Each share entitles the owner to an equal share of the water to which the company is entitled. The shareholders are also permitted to divert at any point desired and apply the water on any ex-company land they desire.

Decree C-125, as entered in 1936, recognized the rights defined in Decree 731 as to priority, amount and place of use and defined other storage and diversion rights. In addition, the court took notice of application for storage rights at Pickel and Leavitt Meadows by the Walker River Irrigation District. Applications 1097 and 1098 were filed with the State Water Commission of California (now State Water Rights Board) on September 30, 1918. Permits 2534 and 2535 were issued June 18, 1926. Provision was made in the decree for storage rights at these sites subject to final action by the State. These permits were revoked by the State Water Rights Board in 1961.

The decree was supplemented in 1953 by "Rules and Regulations for the Distribution of Water, of the Walker River Stream System under Provisions in Paragraph 15 of the Decree in Equity No. C-125." These rules and regulations were formulated by the Board of U.S. Water Commissioners, which administers the decree, and submitted to the court for approval.

The rules and regulations for the distribution of water provide that when natural flow is available in excess of the rights described in Decree C-125, such surplus of floodwater shall be divided in proportion to the vested rights. Under this provision, the Antelope Valley Mutual Water Company has diverted up to 114 second-feet of surplus water. In the event that additional storage facilities are constructed to regulate the surplus water, such diversions will be greatly reduced.

Decree C-125 is an adjudication of most of the irrigation rights of the stream system. However, the court did not define domestic rights, irrigation uses on national forest land and some private riparian lands, and the storage rights of the Walker River Indian Reservation. To date, domestic uses have been small, scattered, and unregulated. Should there be a substantial increase in this type of use, the relative rights of domestic users and irrigators may have to be determined.

The Little Walker Cattlemen's Association is permitted by the Federal Watermaster to divert surplus water for irrigation of unadjudicated private and federal lands in the Little Walker River Watershed. Decree C-125 provides that the Walker River Indian Reservation shall have the right to divert 26.25 second-feet for the irrigation of 2,100 acres with a priority of 1859. In 1934, the Indian

Service constructed Weber Reservoir in Nevada. By use of this reservoir which has a usable capacity of 13,000 acre-feet, 3,100 to 5,000 acres have been irrigated.

Administration of Decree C-125

Section 15 of Decree C-125 provides that:

> " . . . the Court whenever it shall deem necessary, shall appoint a watermaster, who shall be charged with the duty of apportioning and distributing the waters of the Walker River, its forks and tributaries in the State of Nevada and in the State of California, including water for storage and stored water, in accordance with the provisions of this decree."

This provision of the decree was implemented by the court appointment of a Board of U.S. Water Commissioners to act as watermaster. The board is comprised of local ranchers who represent the West Walker River in California, the West Walker River in Nevada, the East Walker River above Bridgeport Dam, the East Walker River below Bridgeport Dam, and the Main Walker River in Mason Valley, and a representative of the Walker River Indian Reservation. The board employs a Chief Deputy Water Commissioner and a secretary.

The Chief Deputy Water Commissioner distributes the water of the river system, making such measurements and computations as are necessary to determine the amounts of water to which the various users are entitled. Actual regulation of water is accomplished largely by deputy watermasters who are also employees of the Walker River Irrigation

District. Water is distributed in conjunction with their duties of distributing storage water belonging to the irrigation district. Costs of watermaster service are charged to the water users in proportion to the acreage of lands irrigated.

Decree C-125 covers both the West Walker and East Walker Rivers and the main stem of the Walker River. For purposes of administration, the river system is divided into the "West and Main Walker River Unit," and the "East Walker River Unit." When the flow of the system becomes insufficient for service of all adjudicated direct diversion rights, the Chief Deputy Water Commissioner makes daily computations of the total water available for diversion in the stream system for each of these two divisions. The total water available for diversion is compared with a tabulation of total natural flow rights to determine the year of priority which can be served. When the year of priority has been determined, all water users with a priority of that date or earlier are served their proportionate share of the available water supply. Occasionally, when the year of priority determined for the East Walker River is later than that on the "West and Main Walker River Unit," sufficient water is allowed to enter the Main Walker from the East Walker to equalize the priorities served in the two units.

Table 6, compiled from the records of the Board of U.S. Water Commissioners, lists the dates of priority and amounts of water to meet the various appropriative rights.

The following computation to determine total water available for diversion within the system on July 1, 1960, was taken from the records of the Chief Deputy Watermaster and is an example of the daily computation made throughout the season. Flows at gaging stations used in the computation are for June 30, 1960.

		Flow in second-feet
West Walker River near Coleville (Antelope Gage)		158
Antelope Valley Diversions		-142
Down River from Antelope Valley		16
Topaz Lake Adjustment		
6-29-60 Lake Contents	16,619 af	
6-30-60 Lake Contents	16,388 af	
Decrease in Contents	231 af	115
Evaporation		- 14
Decrease in Storage		101
West Walker River at Hoye Bridge (Hoye Gage)		200
Change in Storage		-101
Down River from Antelope Valley		- 16
Antelope Valley Return Flow		83
West Walker River at Hoye Bridge (Hoye Gage)		200
Smith Valley Diversions		- 81
Down River from Smith Valley		119
West Walker River at Hudson (Hudson Gage)		138
Down River from Smith Valley		-119
Smith Valley Return Flow		19

Summation of Available Water	
Antelope Gage	158
Antelope Valley Return Flow	83
Smith Valley Return Flow	19
East Walker River	5
East Drain Return	3
Subtotal	268
Indian deficiency	- 7
TOTAL WATER AVAILABLE	261

Year of priority equaled or exceeded from Table 6, 1869

The total water available as determined in this computation, consists of runoff measured at the Junction Gage (West Walker River below Little Walker River near Coleville, California,) and all usable return flows. Natural runoff below Junction Gage is accounted for as Antelope Valley return flow. No measurement is made of the water available from the East Walker River and East Drain; these values are estimated.

The quantities of flow down the river, return flows and evaporation are small in relation to the total flow at the various gages, including released stored water. Therefore, a high degree of precision is required in operation of the various gaging stations.

In addition to administration of direct diversion rights, the federal watermaster also regulates storage rights. Water may be stored only when the direct diversion rights being served have a priority which is equal to or later than that of the storage right. Water from storage is released and conveyed to the place of use through the same system that is used by the direct diversion rights. Poore Lake on Poore Creek in the Pickel Hydrographic Unit, the principal storage reservoir serving lands in California, is subjected to a conveyance loss of 45 percent at the diversion point in Antelope Valley. Water released from Topaz Lake Reservoir for use in Nevada is not reduced for conveyance loss.

The natural flow of the West Walker River is insufficient to supply the natural-flow rights of the lands in Antelope Valley during the latter portion of the irrigation season. At such times as the Antelope Valley rights exceed the supply, the federal watermaster permits the ranchers in Antelope Valley to divert all of the water in the river and does not attempt regulation. This situation, in which the valley is entitled to divert more water than is in the river, rises out of the relationship between priorities in California and Nevada. With an 1864 priority, the California lands are entitled to diversion of 180 second-feet out of total rights of 292 second-feet, whereas the lands in Nevada having the same priorities are entitled to only 49 second-feet out of total rights of 448 second-feet. Return flows resulting from irrigation in California and application of both storage and natural-flow water in Nevada are usually sufficient to supply natural-flow rights in Nevada with a priority of about ten years later than those being served in California.

TABLE 6

SUMMARY OF NATURAL FLOW RIGHTS AND PRIORITIES[1]

In second-feet

Year	Antelope Valley	Smith Valley	Mason Valley diversions: West Walker	Mason Valley diversions: Main Walker	Total annual	Accumulated total	West Walker[2] above Antelope Valley
1861	0	0.08	1.60	0	1.68	1.68	5.12
62	18.13	0.173	0.96	1.20	20.463	22.143	0
63	65.31	18.718	2.96	3.04	90.028	112.171	7.76
64	74.09	11.632	1.20	7.50	94.422	206.593	0
1865	3.40	4.16	0	5.07	12.630	219.223	1.28
66	2.40	2.54	0	0	4.94	224.163	0
67	0	0	0	0	0	224.163	0
68	2.24	2.018	7.36	9.60	21.218	245.381	0
69	0.64	0.37	1.68	6.96	9.650	255.031	0
1870	1.60	2.40	0.64	28.85	33.490	288.521	0
71	0	0	0	3.34	3.34	291.861	0
72	2.68	0	9.84	14.55	27.070	318.931	2.56
73	0	0	0	8.72	8.72	327.651	0
74	2.16	0	0	33.565	35.725	363.376	0
1875	0	2.24	0.48	26.96	29.68	393.056	0
76	2.40	0	0	0	2.40	395.456	0
77	0	9.60	7.55	7.04	24.19	419.646	4.72
78	34.02	14.603	0	3.95	52.573	472.219	0
79	0	0	2.88	13.39	16.27	488.489	0
1880	0	5.24	0.70	47.603	53.543	542.032	0
81	0	0	0	0.48	0.48	542.512	0.64
82	22.62	1.05	2.08	1.88	27.630	570.142	0
83	0	1.13	2.77	0.36	4.26	574.402	0
84	0	1.78	0	0.48	2.26	576.662	6.08

TABLE 6 (continued)

SUMMARY OF NATURAL FLOW RIGHTS AND PRIORITIES1/

In second-feet

Year	Antelope Valley	Smith Valley	Mason Valley diversions: West Walker	Mason Valley diversions: Main Walker	Total annual	Accu-mulated total	West Walker2/ above Antelope Valley
1885	1.06	3.52	2.40	12.592	19.572	596.234	0
86	2.56	0	0	0	2.56	598.794	1.28
87	0	0	0	0.78	0.78	599.574	0
88	0.64	0	0.80	0.96	2.40	601.974	0
89	1.68	0	0	0.60	2.28	604.254	0
1890	2.40	20.89	2.08	4.273	29.643	633.897	0
91	0.64	0	0.96	1.87	3.47	637.367	0
92	0	0.56	0	1.06	1.62	638.987	0
93	0	0	0	0.18	0.18	639.167	0
94	0	0	0.51	0.18	0.69	639.857	0
1895	0.64	3.84	0	3.033	7.513	647.370	0
96	0.64	0	0	1.10	1.74	649.110	0
97	3.20	3.54	0	0.59	7.330	656.440	0.24
98	0	0	0	1.26	1.26	657.700	0
99	0.32	0	0.16	0.14	0.62	658.320	0
1900	0.64	0.80	1.49	10.466	13.396	671.716	0
01	0	0	0	0.18	0.18	671,896	0
02	5.60	0	0	0.11	5.71	677.606	2.88
03	0	0	0.48	0	0.48	678.086	0
04	0	0	0	0.91	0.91	678.996	0

TABLE 6 (continued)

SUMMARY OF NATURAL FLOW RIGHTS AND PRIORITIES[1/]

In second-feet

Year	Antelope Valley	Smith Valley	Mason Valley diversions: West Walker	Mason Valley diversions: Main Walker	Total annual	Accumulated total	West Walker[2/] above Antelope Valley
1905	0	1.44	1.52	8.457	11.417	690.413	0
06	0	0	0	0.24	0.24	690.653	0
07	0	0	0	0	0	690.653	0
08	0	0	0	0	0	690.653	0
09	0	1.00	0	0	1.00	691.653	0
1910	0	3.49	0	0	3.49	695.143	0
11	0	0	0	0	0	695.143	0
12	0	1.851	0	0	1.851	696.994	0
13	0	0	0	0	0	696.994	0
14	0	2.60	0	0	2.60	699.594	0
Riparian							8.05
TOTALS	251.71	121.265	53.10	273.519	699.594		40.61

1/ Copied from records of the Board of United States Water Commissioners.
2/ Not included in totals.

CHAPTER IV. WATER REQUIREMENTS

In studying the water requirements of an area, it is necessary to know how much water is presently being used and to estimate the probable magnitude of use in the future.

Most of the water presently consumed in the West Walker River Basin is used for irrigated agriculture, a situation likely to continue. But there will be inevitable changes in agricultural cropping patterns and associated water uses, and in use of water for urban, recreation, and industrial purposes.

In order to provide a firm foundation upon which to base projections of water requirements a land classification survey was made and present land and water use in each hydrographic unit were inventoried. This inventory provided the basis for an analysis and projection of future land and water uses within the basin. Such usage readily determined the future water requirements.

The land and water use studies showed that the flow of the West Walker River is insufficient to provide a full water supply to all lands in California for which water rights are presently claimed. Consequently, the future development of the West Walker River Basin will be limited by the scarcity of water.

In reading this chapter, reference to Plate 4, "Classification of Lands for Water Service," will be most helpful.

Land Use and Classification

For the purpose of determining both present and probable future water requirements, land classification and present land use surveys were conducted during 1955 and 1956. These surveys determined the nature, location, and areal extent of the present and probable future water using areas.

Field mapping of these areas was done on aerial photographs by land and water use analysts. The area was covered as completely as roads and trails permitted. After completion of field mapping, the delineations were transferred to a planimetric base. The areas were then measured and tabulated by hydrographic unit. The areas which were developed in 1956, and private lands and public domain suitable for future development for residential, commercial, and agricultural purposes are delineated on Plate 4.

Present Land Use

The present land use survey categorized lands into two major groupings, agriculture, and urban and recreation.

Agricultural lands include those utilizing water directly from a high water table as well as those to which water, in addition to direct precipitation, is presently applied. The irrigated areas shown in Table 7 are net areas, and exclude land occupied by roads, farmsteads, and small parcels of nonirrigated land within the irrigated areas.

Due primarily to the short growing seasons and the high elevations at which the agricultural lands lie, forage, hay, and grain are essentially the only crops grown at the present time. Because of the importance of water rights in the basin, it is necessary to distinguish between lands which are partially supplied from an artificial source and those entirely dependent upon a natural source. The following agricultural groupings used in this bulletin take this difference into account:

1. Lands with irrigation facilities and which are usually cropped with alfalfa, grain, better quality native grasses, select grasses, legumes, etc., are classified as irrigated pature.

2. Lands utilizing water directly from a natural high water table and generally supporting a poorer quality forage such as rush and wire grass are classified as natural meadow pasture.

Since determination of water requirements was the primary objective, no distinction was made between small grains threshed and those baled as hay nor between pasture or alfalfa used for forage or cut for hay.

Lands in the urban and recreational category include camp and trailer sites, permanent and summer home areas, motels and resorts, and the other commercial establishments necessary to service these developments. The urban and recreational areas are gross delineations, including homes, streets, vacant lots, etc., and are not necessarily fully developed at the present time.

Acreages of present land use in each hydrographic unit of the West Walker River Basin are presented in Table 7.

TABLE 7

1956 LAND USE

(Net area in acres)

Land Use	Hydrographic Unit					
	Antelope	Lost Cannon	Pickel	Slinkard	Wheeler	Totals
Alfalfa	460	0	0	0	0	460
Pasture	10,310	1,000	560	380	900	13,150
Grain	230	0	0	0	0	230
Total irrigated	11,000	1,000	560	380	900	13,840
Natural meadow pasture	590	210	790	30	1,030	2,650
Total agricultural	11,590	1,210	1,350	410	1,930	16,490
Urban and recreational 1/	110	0	30	0	0	140
Unit totals	11,700	1,210	1,380	410	1,930	16,630

1/ Values are gross acreages.

Land Classification

The lands in the area of investigation were segregated into five broad classifications to indicate their adaptability for agricultural, recreational, urban, and other uses and as irrigable forest and range lands. Lands falling within each of these classifications are discussed below.

Irrigable Lands. The extent and location of the irrigable lands were determined by field surveys which grouped all lands into appropriate classifications according to their suitability for irrigated agriculture and their crop adaptability. The classification was based, to a large extent, on present agricultural practices which provided a direct approach in estimating the probable future crop pattern under conditions of full development. The lands were classified according to the soil characteristics and the physiography. Each of these items directly affects the degree of suitability of the land for irrigation and each remains relatively constant throughout extended periods of time. Consideration was not given to economic factors related to crop production and marketing or to the location of a water supply or its cost, because such factors vary with time. These latter factors, however, are considered in developing future patterns of land use. Climatic conditions, while not a factor in the physical classification of the lands, were considered to be very important in determining the probable future crop pattern.

Considerable emphasis was placed upon the classification of irrigable lands and the projection of a probable future cropping pattern. This was necessary as lands in this category have the greatest effect on the total water requirement in the basin. The magnitude of water required for other classifications of land is small in comparison.

In subdividing the irrigable lands into crop-adaptability classes, lands were first segregated into three broad topographic groups: Smooth lying valley lands, gently sloping and undulating lands, and steeper and more rolling lands. Where one or more conditions that affect the suitability of the lands to produce climatically adapted crops were present, the three broad topographic classes were further subdivided in accordance with the nature of such conditions. These conditions included shallow soil depths, rockiness, high water tables, coarse textures with a low moisture-holding capacity, and the presence of an excess of soluble salts or exchangeable sodium.

The character of the soils was established by examination of road cuts, ditch banks, and material from test holes, together with observation of the type and quality of native vegetation and crops. The presence of rock, high water tables, and salinity also were observed. Representative slopes throughout the area were measured with a clinometer to determine their degree of slope. By giving consideration to all these factors, the appropriate crop-adaptability class for each parcel of land was determined and delineated on aerial photographs.

Results of the land classification survey indicate that approximately 30,860 acres of land in the West Walker River Basin are susceptible to agricultural development. Approximately 16,440 acres or some 53 percent of the lands classed as irrigable, are valley lands. A very large part of these valley lands are subject to high water tables and are presently devoted to the production of meadow pasture. Except for relatively minor areas, it is expected that this condition will not change in the future. Practically all of these irrigable valley lands are composed of Recent alluvial and lacustrine soils.

Under the adopted classification standards, irrigable hill lands include those which fail to meet the requirements for irrigable valley lands in regard to topography, but which are suitable for irrigation development and for the production of certain crops. Some of the irrigable hill lands are found on Recent alluvial soils, but for the most part they comprise residual soils or old valley-terrace soils. The best of the irrigable hill lands, those with adequate soil depth, free from rock, and with reasonably smooth topography, amount to about 7,890 acres, or approximately 26 percent of the total irrigable area. The remainder of the irrigable hill lands, totaling some 6,530 acres or about 21 percent of the irrigable area, have inadequate soil depths, rock or excessive slopes.

Urban Areas. With two exceptions, the urban areas were considered to be the same size in the future as they are at the present time. The reason that these areas are not expected to increase in size is that they are not presently fully developed and contain considerable vacant land for future growth.

As the first exception to the foregoing, it will be noted in the tabulations that the acreage of future urban areas, in some instances, is less than that of the present urban areas. This is due to the fact that when recreational lands overlapped urban areas, these duplicated lands were considered to be a part of the recreational area. Secondly, some additional commercial and residential development was projected for the recreational areas.

Recreational Areas. Certain irrigable lands in the area appear to be committed to recreational development because of present development and others were considered to have a greater potential for recreational use than for other uses. These lands were segregated according to the nature of existing and expected future development, including camp and trailer sites, permanent and summer home areas, motels and resorts, and other commercial establishments necessary to service these developments.

Irrigable Forest and Range Lands. Lands placed in this category have soils and physical characteristics which, under the adopted classification standards, make them suitable for irrigation development. However, due to their physiography, climatic conditions, and other factors associated with their present utilization, they were classified as best suited to remain under some type of forest or range management classification. These lands are located in the

Toiyabe National Forest and their use is subject to control by the United States Forest Service.

The soils of these lands are usually of the residual type, normally associated with conifer production where rainfall is adequate or dry range in areas of low precipitation. Since the economy of the area is greatly influenced by the production of livestock, with an accompanying demand for range land, particularly in the national forests, it appears reasonable that the marginal land classes would remain as grazing lands under general forest management practices.

Other Lands. All those lands which do not meet the criteria of the previous classifications were placed in this category. These lands will probably continue to be used in their natural condition for recreation, grazing and timber production without the need for artificial water supplies.

Acreages of the various classifications of lands in the West Walker River Basin are listed in Table 8. These data are expressed in gross acres unadjusted for probable areas of streets or roadways, farmsteads, canals, and similar land uses.

Probable Future Land Use

It is necessary to determine the probable future use of land in the area in order to estimate the water use

TABLE 8

CLASSIFICATION OF LANDS

(Gross area in acres)

Land Class*	Hydrographic Unit: Antelope	Lost Cannon	Pickel	Slinkard	Wheeler	Totals
V	600	440	90	130	20	1,290
Vw	8,180	100	1,070	130	1,220	10,700
Vs	510	0	0	0	0	510
Vl	3,170	20	10	0	30	3,230
Vr	180	0	20	0	10	210
Vrl	500	0	0	0	0	500
H	890	620	0	2,640	2,680	6,830
Hl	1,000	50	10	0	0	1,060
Hp	0	0	0	0	130	130
Hr	1,110	600	640	1,140	300	3,790
Hrl	500	1,190	30	0	0	1,720
Ht	0	140	0	0	390	530
Htr	0	40	30	150	140	360
TOTAL IRRIGABLE	16,640	3,200	1,900	4,190	4,930	30,860
U	40	0	30	0	10	80
Ra	90	0	10	0	0	100
Rb	290	0	0	0	0	290
Rc	20	0	1,950	110	1,560	3,640
TOTAL URBAN AND RECREATION	440	0	1,990	110	1,570	4,110
F	60	500	0	0	70	630
N	38,050	21,900	69,140	14,850	65,120	209,060
UNIT TOTALS	55,190	25,600	73,030	19,150	71,690	244,660

*Key to classification.

Agricultural lands most suitable for irrigation:

Primary classification
- V - smooth-lying valley lands
- H - gently sloping and undulating lands
- Ht - steep and rolling lands
- U - urban 1956

Sub classes
- w - high water table
- s - saline soil
- l - light texture
- r - rocky
- p - depth limitation

R - lands best suited for recreation, residential and commercial use
- a - commercial
- b - summer home areas or tracts
- c - camp and trailer sites

F - irrigable land best suited to forest or range management

N - land which does not meet standards of previous classifications which may actually occur in the area of investigation in the future. The probable future land use estimate was based upon the land classification and present land use evaluations as limited by the water supply in the area.

There are about 138,000 acres of land in the entire Walker River Basin in California and Nevada which have either adjudicated irrigation rights or the right to service from Walker River Irrigation District reservoirs. The consumptive use of water on this land, if a full water supply were available, would be about 386,000 acre-feet, which is greater than the 349,770 acre-feet average annual inflow to the Antelope and Bridgeport Valleys. Obviously there is not sufficient water to assure a full water supply to all of the land for which water rights are claimed. For this reason, it was assumed in estimating the probable future use of land in this report that (1) irrigation would be limited to the area which was irrigated in 1956, and (2) future development in the California portion of the Walker River Basin would be limited to recreation, including related residential and commerical land uses.

In accordance with these assumptions, the area estimated to be devoted to irrigated agriculture in the future was limited to that which was devoted to this use in 1956. Estimates of future urban and recreational land use were made for private and public lands. Undeveloped private lands within the area of investigation were reclassified with respect to the population densities which might reasonably be expected to occur in the area during the peak of the summer recreation season. Factors considered in this reclassification were:

1. Proximity to a lake, stream, or reservoir.

2. Type of vegetative cover (forest, sagebrush, etc.)

3. Soil depth.

4. Rockiness.

5. Slope.

6. Climatic environment.

7. View.

Under this method of projecting land use, lands which were classified as suitable for agricultural use, but which also can be utilized for recreational use under this procedure were assumed to be used for recreational purposes in the future.

An estimate of the future use of national forest lands was supplied by the Supervisor of the Toiyabe National Forest.

Lands included under the subheading "Other" are those public and privately owned lands in the basin which will continue to be used for grazing, timber production, and recreation without need for application of water in addition to natural precipitation.

The estimated future level of development based upon these assumptions, is shown in Table 9.

Future Water Use

Estimates of future water use in the area of investigation were based upon the estimates of probable future land use. Water requirements for irrigation, municipal, industrial, hydroelectric power, and recreational use were appraised. Water use for each of these functions is not additive as there is reuse and also some duplication between consumptive and nonconsumptive use.

Irrigation Requirements

Irrigation requirements are usually discussed in terms of consumptive use of applied irrigation water, farm delivery requirements, or diversion requirements. Estimates for this report are in terms of consumptive use of applied water and farm delivery requirements.

Consumptive use is the quantity of water removed by vegetation and that lost by evaporation for a particular area during a specified time.

The diversion requirement is the quantity of water which must be diverted at the source in order to supply the farm delivery requirement. This quantity is usually computed as the farm delivery requirement plus conveyance losses less waste water contributions to the ditch.

TABLE 9

PROBABLE FUTURE PATTERN OF LAND USE

(Net area in acres)

Land Use	Hydrographic Unit					
	Antelope	Lost Cannon	Pickel	Slinkard	Wheeler	Total
Agricultural						
Alfalfa	460	0	0	0	0	460
Pasture	10,310	1,000	560	380	900	13,150
Grain	230	0	0	0	0	230
Subtotal Irrigated	11,000	1,000	560	380	900	13,840
Natural Meadow Pasture	590	210	790	30	1,030	2,650
Subtotal Agricultural	11,590	1,210	1,350	410	1,930	16,490
Urban and recreational						
Commercial	540	40	0	0	310	890
Residential	5,540	1,930	120	0	1,180	8,770
Campgrounds	190	120	870	0	590	1,770
Subtotal Urban and Recreational	6,270	2,090	990	0	2,080	11,430
Other*	12,560	5,410	1,830	14,080	4,890	38,770
Total	18,830	7,500	2,820	14,080	6,970	50,200
GRAND TOTAL	30,420	8,710	4,170	14,490	8,900	66,690

*Unclassified private lands and public domain.

The farm delivery requirement is the quantity of water which must be delivered at the farm headgate in order to satisfy the demand for consumptive use plus losses, including farm distribution system losses, reasonable surface outflow from the fields and deep percolation.

These requirements may be expressed in terms of rate of use in second-feet (cubic feet per second) or volume of use in acre-feet or acre-inches. Unit use is the number of second-feet, acre-feet, or acre-inches per acre. Water requirements for the area of investigation and the individual hydrographic units are computed as the product of area in acres and unit water use requirement.

Duty of water is the number of acres which can be irrigated with one second-foot of water. However, in "The Rules and Regulations for the Distribution of Water of the Walker River Stream System Under the Provisions of Paragraph 15 of Decree in Equity No. C-125," duty of water is expressed in terms of cubic feet per second per 100 acres of land.

Consumptive Use of Applied Irrigation Water. The method of estimating consumptive use of water from all sources was developed by the University of California at Davis, augmented by field studies conducted by the California Department of Water Resources. These studies indicated that consumptive use could be computed from data on evaporation obtained locally from black and white atmometers and from coefficients of consumptive use of individual crops elsewhere determined by actual soil-moisture-depletion measurements. Modifying factors such as length of growing season, percentage of plant ground cover, available soil moisture and rainfall were considered in the computations.

Determinations of monthly and seasonal consumptive use of water from all sources by crops grown in the area of investigation were based on coefficients developed by the University of California at Davis and from atmometer data collected by the Department of Water Resources during 1955, 1956, and 1957. Crop types are few in number. For consumptive-use determinations, these crops were placed in groups on the basis of like water-consuming characteristics. These crops and their corresponding coefficients of consumptive use, together with their growing seasons, are tabulated below:

Crop	Coefficient of consumptive use*	Length of irrigation season
Alfalfa and pasture	.0134	April 15 through September
Riparian meadowland, meadow pasture, and induced high water table pasture	.0134	April 15 through September
Irrigated grain	.0134	May through July

*Inches of evapotranspiration per milliliter of difference between evaporation of black and white spherical atmometers.

The length of irrigation season for these crops was obtained from observation and climatological records of temperature and frost periods which govern the active growing season. The original consumptive-use values, which were utilized to determine the coefficients listed, were derived for conditions of constant optimum soil moisture for plant growth. In practice, irrigations are often so spaced that plant requirements are not always fully satisfied.

Atmometer data, comprising the differences between monthly evaporation rates of black and white atmometers, were obtained in the area of investigation during 1955 and 1956 from stations at or near Coleville, Bridgeport, Woodfords, and Boca Dam for the months of June through September. Data for May was not obtainable locally because of the possibility of freezing the water-filled atmometer bulbs. Atmometer values utilized for that month were obtained from data collected in the Pit River drainage area during 1955 and 1957. The average of these values for the months of May through September are respectively: 440, 580, 600, 570, and 460 milliliters.

The previously tabulated coefficients of consumptive use were multiplied by the aforesaid atmometer values to estimate the amounts of water from all sources consumed each month by evaporation and transpiration. Consumptive use of applied irrigation water was obtained by subtracting from this product the precipitation which occurs during the growing season, together with that quantity of original soil moisture assumed to have been removed between the beginning and the end of the irrigation season. Unit consumptive use values of applied water so obtained are shown in Table 10.

The volume of consumptive use of applied water in each hydrographic unit, as shown in Table 11, was computed as the product of area of present land use and unit values given in Table 10. Present water supply limitiations were not considered in this estimate.

Farm Delivery and Diversion Requirements. The estimated diversion requirements were based on analysis of the records of the Antelope Valley Mutual Water Company for the period 1953 through 1955 and on measurements of field deliveries and surface outflow in 1956. Lands were grouped into the following categories: (1) meadowlands, (2) alluvial aprons, and (3) the rocky, light-textured river terrace deposits at the head of Antelope Valley. Field observations indicated that during the month of July in most years, the supply was barely adequate to meet the demand.

The diversion requirements shown for the months of March and October primarily represent the use of water needed to work the land and to account for the practice of irrigating during these months.

Table 12 presents figures relating to some of these diversions.

TABLE 10

ESTIMATED UNIT CONSUMPTIVE USE OF APPLIED IRRIGATION WATER

Hydrographic unit and crop	Monthly values in inches						Seasonal Totals	
	April	May	June	July	Aug.	Sept.	Inches	Feet
Antelope								
Alfalfa and pasture	2.0	5.4	7.5	7.8	7.4	4.0	34.1	2.8
Grain (irrigated)		4.0	7.5	3.9			15.4	1.3
Lost Cannon and Slinkard								
Alfalfa and pasture	2.0	5.4	7.5	7.8	7.4	0.9	31.0	2.6
Meadow pasture	2.0	5.4	7.5	7.8	7.4	0.9	31.0	2.6
Grain		4.0	7.5	3.9			15.4	1.3
Pickel								
Pasture		3.5	7.5	7.8	5.4		24.2	2.0
Meadow pasture		3.5	7.5	7.8	5.4		24.2	2.0
Wheeler								
Pasture		3.5	7.5	7.8	5.4		24.2	2.0
Meadow pasture		3.5	7.5	7.8	5.4		24.2	2.0

TABLE 11

ESTIMATED CONSUMPTIVE USE OF APPLIED IRRIGATION WATER
BY HYDROGRAPHIC UNITS

(In acre-feet)

Month	Antelope	Lost Cannon	Wheeler	Subtotal	Pickel	Slinkard	Total
April	1,790	170		1,960		60	2,020
May	4,930	450	260	5,640	160	170	5,970
June	6,870	630	560	8,060	350	240	8,650
July	7,070	650	580	8,300	360	250	8,910
August	6,640	620	400	7,660	250	230	8,140
September	3,590	80		3,670		30	3,700
TOTALS	30,890	2,600	1,800	35,290	1,120	980	37,390

TABLE 12

UNIT FARM DELIVERY REQUIREMENTS FOR IRRIGATION OF PASTURE

Category	Meadowland	Alluvial Apron Lower Portion	Alluvial Apron Upper Portion	River Terrace
Irrigation Classification* Primary	V	Vl & H	H	V
Subclass	all except l & r	all except r & t	r & t	r
Ground Water Basin Class as shown on Plate 4	B	A	A	A
Requirement in acre-feet per acre				
March	.1	.2	.3	.3
April	.5	.8	1.0	1.0
May	.9	1.5	1.7	1.7
June	.9	1.5	1.8	1.8
July	.9	1.5	1.8	1.8
August	.6	1.1	1.3	1.3
September	.5	.8	.9	.9
October	.1	.2	.3	.3
TOTAL	4.5	7.6	9.1	9.1
Duty in acres per second-foot	67	40	33	33
Duty in cfs per 100 acres	1.5	2.5	3.0	3.0

* See explanation in notes to Table 8.

The volume of water which must be diverted during the irrigation season, presented in Table 13, was estimated by multiplying unit farm delivery requirement values by the area irrigated. For a large area such as Antelope Valley, conveyance losses are balanced by return flows, which are picked up in the distribution system. However, in estimating diversion requirements for individual farms, particularly those at the perimeter of the valleys, conveyance losses must be added to the farm delivery requirement. For small fields close to the source, farm delivery and diversion requirements are the same.

Municipal Water Requirements

Water requirements for recreational, residential, and commercial areas were estimated as the sum of the products of the area suited for each use and the unit municipal water requirement for that use based on demand factors developed jointly with the Nevada State Engineer for estimates of future water use in the Lake Tahoe Basin. Domestic water requirements for the local farm population were not estimated. It was assumed that the needs of this group could be met from the irrigation requirement. The results of this estimate are presented in Table 14.

TABLE 13

ESTIMATED PRESENT FARM DELIVERY REQUIREMENTS
BY HYDROGRAPHIC UNIT

(In acre-feet, except as noted)

Month	Hydrographic unit						
	Antelope	Lost Cannon	Wheeler	Subtotal	Pickel	Slinkard	Total
March	1,660	270	130	2,060	60	100	2,220
April	7,110	1,020	560	8,690	280	330	9,300
May	12,860	1,820	1,020	15,700	510	590	16,800
June	12,990	1,910	1,050	15,950	510	620	17,080
July	12,970	1,880	1,040	15,890	510	620	17,020
August	9,040	1,330	710	11,080	350	420	11,850
September	6,990	960	560	8,510	290	310	9,110
October	1,660	270	130	2,060	60	100	2,220
TOTAL	65,280	9,460	5,200	79,940	2,570	3,090	85,600
Delivery rate in cfs	219	32	18	269	9	10	288

TABLE 14

ESTIMATED FUTURE MUNICIPAL WATER REQUIREMENTS

Hydrographic Unit and Land Use	Acres	Acre-feet per Acre	Total Annual Water Requirements in Acre-feet
<u>Antelope</u>			
Commercial	540	2.07	1,120
Residential	5,540	.28	1,590
Campgrounds	190	.32	60
Subtotal	6,270		2,770
Other*	12,560	.025	310
H.U. Total	18,830		3,080
<u>Lost Cannon</u>			
Commercial	40	2.08	80
Residential	1,930	.28	540
Campgrounds	120	.33	40
Subtotal	2,090		660
Other*	5,410	.025	140
H.U. Total	7,500		800
<u>Pickel</u>			
Commercial	0	0	0
Residential	120	.25	30
Campgrounds	870	.22	190
Subtotal	990		220
Other*	1,830	.025	50
H.U. Total	2,820		270
<u>Slinkard</u>			
Other*	14,080	.025	350
H.U. Total	14,080		350
<u>Wheeler</u>			
Commercial	310	2.00	620
Residential	1,180	.41	490
Campgrounds	590	.25	150
Subtotal	2,080		1,250
Other*	4,890	.025	120
H.U. Total	6,970		1,380
GRAND TOTAL	50,200		5,880

*Unclassified private lands and public domain assumed to have a population density of 0.4 persons per acre.

Industrial Water Requirements

Industrial uses of water in this area are apparently limited to the forest product and mining industries. The possibility that other industries may locate in the area in the future appears remote. No estimates of the water requirements of the forest product and mining industries were made as the available information regarding these small and intermittent industries indicates such uses would be negligible.

Water Requirements for Hydroelectric Power

Hydroelectric energy could be developed between Leavitt Meadows and the head of Antelope Valley. The Leavitt-Pickel project proposed in this report would have an installed capacity of 31,500 kilowatts and an average annual energy output of 98,700,000 kilowatt hours. The 88,350 acre-foot average annual discharge through the lower powerplant corresponds to a continuous flow of 122 second-feet.

Hydroelectric power generation is not entirely compatible with irrigation. Peak demand for power in western Nevada occurs in December and January whereas the peak demand for irrigation water is in June and July. Fortunately, the magnitude of the irrigation demand upstream from Topaz Lake is such that these conflicting uses could be reconciled by reducing the winter releases to the minimum required to support the dependable generating capacity and reregulation of winter power releases in Topaz Lake for irrigation use in Nevada. The greatest conflict between power and irrigation would occur in the Pickel and Wheeler Hydrographic Units. Water used consumptively in these units would not be available for power generation downstream. Conversely, power development would either inundate most of the irrigated area or bypass it with the power conduit.

Recreational Water Requirements

Recreational uses of water include those which are needed for domestic, aquatic sports, aesthetic, and fish and wildlife maintenance purposes. Estimates of domestic use in connection with recreation have been previously discussed and the requirements presented in Table 14. Other recreational uses may be included in the fishery requirements since, in general, if there is enough water for fish, there is also enough for wildlife, aquatic sports, and aesthetic purposes.

The local recreation industry is dependent on maintenance of streamflow at levels sufficient to provide suitable habitat for fish and provide for optimum natural reproduction. Determination of streamflow maintenance requirements is a complex matter involving consideration of such matters as the physical characteristics of the stream channel, feed, water temperatures, reproductive capacity of the fishery, and species present. Such determinations are made for water projects by the California Department of Fish and Game, pursuant to Section 5937 of the Fish and Game Code, which provides that the owner of any dam shall allow sufficient water to pass the dam at all times in order to keep in good condition any fish which may exist below the dam. Issuance of permits by the State Water Rights Board is subject to Section 1243 of the Water Code, which makes recreation and the preservation and enhancement of fish and wildlife a beneficial use of water.

Streamflow maintenance may conflict with other uses of water. Water required for fish life and recreation remains in the stream and is not available for irrigation or power. The major conflict would be with power generation on the West Walker River. Reaches of that river in which hydroelectric power can be produced are also the areas of greatest fishing pressure. The proposed Antelope power development would convey as much water as possible, in excess of the requirements for fishery maintenance, from Pickel Meadow through a closed conduit to the head of Antelope Valley, thus precluding its use in that area for streamflow maintenance or fishery enhancement.

The quantities of water required for fishery purposes at various reaches of the stream are presented in Table 15. This table was prepared from information submitted to the California-Nevada Interstate Compact Commission by the California Department of Fish and Game in 1960.

TABLE 15

FISHERY MAINTENANCE REQUIREMENTS

(in cfs)

Stream and Section	Period	Minimum Flow
West Fork Walker River		
Topaz Lake to Walker	Jan. 1 - Dec. 31	30
Walker to Little Walker River	Jan. 1 - Dec. 31	100
Little Walker River to Leavitt Meadows	Jan. 1 - Dec. 31	50
Above Leavitt Meadows	Jan. 1 - Dec. 31	25
Little Walker River	Jan. 1 - Dec. 31	20
Rock Creek	Jan. 1 - Dec. 31	5
Lost Cannon Creek	Jan. 1 - Dec. 31	10

CHAPTER V. POTENTIAL WATER SUPPLY DEVELOPMENT PLANS

The water resources of the California portion of the West Walker River Basin have been studied to determine various means by which the water requirements of the area could be met within existing water supply and water rights limitations. This chapter attempts to describe and evaluate several alternative plans which would provide a more dependable water supply for the basin than that which now exists.

In these studies the objective of water supply development was to free the local economy from dependence on the natural flow of the stream by regulation of the available water supply to make floodwaters available in the latter part of the irrigation season and in years of subnormal streamflow. Possible means of accomplishing this objective include construction of surface storage reservoirs, use of ground water, and improvements in irrigation efficiency.

None of the alternative plans proposed in this chapter is sufficient to fully meet all the requirements of the area. Ultimate development of the basin will probably require implementation of more than one of the alternate proposals. It is the responsibility of the local water users to review these proposals and develop a combination of plans that are best suited to their needs.

Alternative Plans

Plans for West Walker River Basin water development are shown on Plate 5, "Possible Water Conservation Projects." These projects can be grouped into five categories: (1) mountain lake storage, (2) new reservoir storage for irrigation, (3) hydroelectric facilities, (4) ground water use, and (5) improvements in irrigation efficiency. Although generation of electrical power would be the primary purpose of hydroelectric facilities, operation could be scheduled to provide release of water for irrigation during the latter part of the summer. Improvements in irrigation efficiency could make the existing water supply go further and thus provide some of the same benefits as additional storage projects.

Design of features of possible plans for development was necessarily of a preliminary nature and primarily for cost estimating purposes. Quantity estimates were made from conservatively proportioned structures using the best materials available locally. Unit prices of quantities were determined from recent bid data on similar projects and from manufacturer's price quotations. The prices are representative of January 1961 price levels. Only one design and cost estimate for each structure was made. Studies to find the optimum economic combination of structure types, components, and sizes were not made. The geologic investigation of damsite and conduit routes included a review of available geologic literature and field inspection.

More detailed investigation and subsurface exploration will be needed to prepare feasibility reports and construction plans and specifications. Further study may result in designs differing in detail from those prepared for this report. However, it is not believed that such modifications will result in significant changes in estimates of cost.

Capital costs have been estimated by increasing the construction costs described above by an allowance for engineering interest during construction and administration. This increase ranged from 14 to 19 percent, depending on the complexity of the structure.

Annual costs were computed using an interest rate of 4 percent per annum on the total investment with a 50-year repayment. The costs of repayment, replacement, and general expense were estimated as a percentage of the capital costs of the project. Operation and maintenance costs were based on various characteristics, depending upon the type of facility.

Mountain Lake Storage

Seven of the larger existing lakes in the watershed above Leavitt Meadow were studied to determine their water conservation potentials. The seven considered were Leavitt, Helen, Bonnie, Ruth, Harriet, Fremont, and Lane Lakes. Storage space could be increased at these sites by constructing check dams at the lake outlets to raise maximum lake levels. Excavation of channels through the natural rim of the lakes would lower the minimum lake levels and enable increased use of the storage. Water made available by this method could be released during August and September to increase the flow of the stream system downstream from the lakes to the head of Antelope Valley to increase the irrigation supply in Antelope Valley and to enhance the stream fishery.

Because the mountain lake project dams would be small, construction costs were estimated on a time and materials basis. Except for the Leavitt Lake Dam, construction could probably be handled by the water users with locally available equipment.

Recreational facilities costing $8,400 were included at Leavitt Lake, which is the only mountain lake project accessible by automobile. Since the need for recreation facilities at the other projects may be very slow in developing, their cost was not included in this report.

The location, size, certain other physical characteristics and the capital and annual costs of the seven lake reservoirs are presented in Table 16. The annual costs are made up of capital recovery and operation and maintenance costs and, in the case of Leavitt Lake, the repayment costs of recreational facilities.

TABLE 16

MOUNTAIN LAKE PROJECTS--LOCATION, PHYSICAL CHARACTERISTICS, AND COSTS

	Leavitt Lake	Helen Lake	Bonnie Lake	Ruth Lake	Harriet Lake	Fremont Lake	Lane Lake
Usable Storage Capacity							
Acre-feet	1,200	100	80	30	40	520	250
Location MDB&M							
Township (N)	5	4	4	4	4	5	5
Range (E)	21	22	22	22	22	22	22
Section	13	21	16	21	16	22	10
Stream	Leavitt Creek	Cascade Creek	Cascade Creek	Cascade Creek	Cascade Creek	Unnamed	Un-named
Approximate Elevation (ft.)1/	9,560	9,640	9,400	9,640	9,240	8,220	7,300
Water Level Fluctuation (ft.)	20	6	5	2	3.5	9.8	10
Type Structure	Earth & Rock	Stone	Stone	Stone	Stone	Stone	Stone
Size2/							
Length, (ft.)	376	238	166	59	197	173	127
Max. Height, (ft.)	33	8	8	2.5	4.5	12	16
Volume, (cu. yds.)	11,370	153	108	6	71	222	127

TABLE 16

MOUNTAIN LAKE PROJECTS--LOCATION, PHYSICAL CHARACTERISTICS, AND COSTS

	Leavitt Lake	Helen Lake	Bonnie Lake	Ruth Lake	Harriet Lake	Fremont Lake	Lane Lake
Capital Cost (in dollars)	59,300	13,800	9,900	1,300	8,200	18,100	10,500
Annual Costs (in dollars)							
Capital Recovery	3,000	700	500	60	410	910	530
O & M	200	20	10	10	10	10	50
Subtotal	3,200	720	510	70	420	1,020	580
Rec. Facilities	8,400	-	-	-	-	-	-
TOTAL	11,600	720	510	70	420	1,020	580
Cost/AF of Usable Storage Capacity (in dollars)	2.70 9.70 3/	7.20	6.40	2.30	10.50	2.00	2.30

1/ From Sonora Pass and Tower Peak, USGS Survey, 15 minute quadrangles.
2/ Main and auxiliary dam.
3/ With recreational facilities.

New Irrigation Reservoir Storage

Opportunities for surface reservoir storage for irrigation exist in the Roolane and Leavitt Meadow areas of the Pickel Hydrographic Unit. Suitable sites were found for construction of reservoirs in the 9,000 to 26,000 acre-foot active capacity range. Three alternative reservoir possibilities at the Roolane site and one at the Leavitt Meadow site were studied for possible development for irrigation, flood control, recreation, and fishery enhancement purposes. The location, size, and other physical characteristics of these projects are summarized in Table 17. The Roolane alternatives have been labeled 9 M, 18 M, and 26 M, corresponding to their storage capacities.

Construction costs were estimated as the sum of the products of individual material quantities indicated from the preliminary design and the unit costs thereof. Because recreation is one of the project purposes, the annual cost of onshore recreational facilities has been included as an annual cost along with operation and maintenance costs. However, since the reservoirs can be constructed without recreational facilities, the unit usable capacity costs have been figured both with and without recreation. Estimated project costs are shown on the lower part of Table 17 for all four alternative new irrigation reservoir projects.

TABLE 17

IRRIGATION PROJECTS--LOCATION, PHYSICAL CHARACTERISTICS, AND COSTS

	Roolane 9M	Roolane 18M		Roolane 26M			Leavitt Meadow
		Main Dam	East Aux. Dam	Main Dam	West Aux. Dam	East Aux. Dam	
Usable Storage Capacity in Acre-Feet	9,000	18,000		26,000			26,000
Location MDB&M							
Township (N)	5	5	5	5	5	5	6
Range (E)	22	22	22	22	22	22	22
Section	10	10	10	10	10	10	27
Stream	W. Walker	W. Walker		W. Walker			W. Walker
Elevation in feet							
Normal pool	7,335	7,372	7,372	7,400	7,400	7,400	7,211
Min. pool	7,260	7,260	7,260	7,260	7,260	7,260	7,123
Difference	75	112	112	140	140	140	88
Type Structure	Rockfill	Rockfill	Earth & Rock	Rockfill	Earth & Rock	Earth & Rock	Earth & Rock
Size							
Length, (ft.)	320	330	145	450	240	266	1,780
Height, (ft.)	112	148	50	177	50	79	126
Volume, (cy. yd.)	123,240	259,320	17,790	359,570	29,444	76,960	498,800
Capital Cost in Dollars	$ 2,302,000		$ 2,968,000			$ 4,116,000	$ 3,134,000

TABLE 17 (continued)

IRRIGATION PROJECTS--LOCATION, PHYSICAL CHARACTERISTICS, AND COSTS

	Roolane 9M	Roolane 18M		Roolane 26M			Leavitt Meadow
		Main Dam	East Aux. Dam	Main Dam	West Aux. Dam	East Aux. Dam	
Annual Costs in Dollars							
Capital recovery	116,100		149,730			207,660	158,100
O & M	2,000		3,800			5,200	6,000
Subtotal	118,100		153,530			212,860	164,100
Rec. Fac.	66,300		66,300			66,300	57,100
TOTAL	184,400		219,830			279,160	221,100
Cost/AF of Usable Storage Capacity (in dollars)	20.50 1/		12.20			10.70	8.50
	13.10		8.50			8.20	6.30

1/ Without recreational facilities.

Hydroelectric Power Projects

The West Walker River drops approximately 1,700 feet in 20 miles between the head of Leavitt Meadow and the head of Antelope Valley. For power purposes, this drop can be broken conveniently into two steps, a 430-foot drop between Leavitt Meadow and Pickel Meadow, and a 1,250-foot fall between Pickel Meadow and the head of Antelope Valley. This situation suggests three alternative plans: (1) a Leavitt Project which would develop the head between Leavitt Meadow and Pickel Meadow, (2) a Pickel Project which would develop the head between Pickel Meadow and the head of Antelope Valley, and (3) a Leavitt-Pickel Project which would be a combination of the two except that the Pickel Reservoir would be smaller in size. The latter two projects would utilize water diverted from the Little Walker River in addition to the runoff of the West Walker River watershed above the Pickel Meadow reservoir site. Small afterbay reservoirs would reregulate the powerplant discharge to a constant flow for irrigation use in Antelope Valley. The location, size, and other physical characteristics of the alternative hydroelectric power projects are shown in Table 18.

Except for powerplants, construction costs were estimated as the sum of the products of individual material quantities indicated from preliminary design and the unit

TABLE 18

HYDROELECTRIC POWER PROJECTS - LOCATION AND PHYSICAL CHARACTERISTICS

Project Unit Structure	Usable Capacity: Units	Usable Capacity: Quantity	Locations* MDB&M: T	Locations* MDB&M: R	Locations* MDB&M: Sec.	Stream	Elevation in feet (USGS Datum): Normal Pool	Elevation in feet (USGS Datum): Min. Pool	Elevation in feet (USGS Datum): Diff.	Type Structure	Size of Structure: Length ft.	Size of Structure: Height or Diam. ft.	Size of Structure: Volume cu. yds.
Leavitt Project													
Leavitt Meadow Reservoir	AF	26,000	6	22	27	West Walker	7,211	7,123	88	Earth and Rock	1,780	126	498,800
Leavitt Power Development													
Tunnel	CFS	406	6	22	34	West Walker				Lined	2,800	7.0	
Penstock	CFS	406	6	22	34					Steel	1,100	6.0	
Powerplant	KW	11,000	6	22	35	Poore Creek		6,783					
Afterbay	AF	540	6	23	19	West Walker	6,715	6,703	12	Earth and Rock	810	36	49,400
Pickel Project													
Pickel Reservoir	AF	65,040	6	23	17	West Walker	6,803	6,703	100	Earth and Rock	1,160	142	1,227,000
Little Walker Diversion Dam			6	23	21	Little Walker	6,900			Concrete			
Canal	CFS	250	6	23	21					Unlined	10,560		
Antelope Power Development													
Tunnel	CFS	300	6	23	17	West Walker				Lined	36,200	7.0	
Conduit	CFS	300	7	23	17					Steel	18,400	6.0	
Siphons (2)	CFS	300	8	23	28					Steel	2,700	6.5	
Tunnel and Surge	-	-	8	23	28					Steel	250	6.0	
Penstock	CFS	300	8	23	28					Steel	1,200	5.0	
Powerplant	KW	22,000	8	23	28	West Walker		5,553					
Afterbay	AF	700	8	23	28	West Walker	5,553	5,519	34	Concrete	374	60	29,320
Leavitt-Pickel Project													
Leavitt Reservoir	AF	27,680	6	22	27	West Walker	7,211	7,123	88	Earth and Rock	1,780	126	498,800
Leavitt Power Development													
Conduit	CFS	406				West Walker				Tunnel	2,800	7.0	
Penstock										Steel	1,100	6.0	
Powerplant	KW	11,000	6	22	35	Poore Creek		6,783					

TABLE 18 (continued)

HYDROELECTRIC POWER PROJECTS - LOCATION AND PHYSICAL CHARACTERISTICS

Project Unit Structure	Usable Capacity		Locations* MDB&M				Elevation in ft. (USGS Datum)			Type Structure	Size of structure		
	Units**	Quantity	T	R	Sec.	Stream	Normal Pool	Min. Pool	Diff.		Length ft.	Height or Diam. ft.	Volume cu. yds.
Little Walker Diversion													
Dam	AF		6	23	21	Little Walker							
Canal	CFS	250								Unlined	10,560		
Pickel Reservoir	AF	35,040	6	23	17	West Walker	6,781	6,703	78	Earth and Rock	1,040	120	850,000
Antelope Power Development													
Tunnel	CFS	300	6	23	17	West Walker				Lined	36,200	7.0	
Conduit	CFS	300	7	23	17					Steel	18,400	6.0	
Siphons (2)	CFS	300	8	23	28					Steel	2,700	6.5	
Tunnel and Surge	CFS	300	8	23	28					Steel	250	6.0	
Penstock	CFS	300	8	23	28					Steel	1,200	5.0	
Powerplant	KW	22,000	8	23	28	West Walker		5,553					
Afterbay	AF	700	8	23	28	West Walker	5,553	5,519	34	Concrete	374	60	29,320

* Damsite, conduit intake or powerplant.
** Units: AF (acre-feet), CFS (cubic feet per second), KW (kilowatts).

costs thereof. Powerplant costs were estimated on the basis of cost per kilowatt of installed capacity for other similar installations.

Annual costs include capital recovery, operation and maintenance, replacement, insurance and general expense, and repayment of recreational facilities. Operation and maintenance costs of dams, powerhouses and penstocks were computed from a schedule based on size. On other facilities, operation and maintenance was estimated as a percentage of capital costs.

A summary of capital and annual costs for the hydroelectric power projects is contained in Table 19.

Ground Water Development

Ground water could be developed for agricultural use in Slinkard Valley. In Antelope Valley, an attractive opportunity exists for coordinating the use of ground and surface water, so as to achieve greater benefits than could be realized independently. Small amounts of ground water could be developed for agricultural use in other areas. Wells could be developed for domestic use in many locations throughout the study area.

The development of the ground water resources described in Chapter II would have the advantages of (1) availability at or near the place of use; (2) little variation in availability during the irrigation season or from year-to-year; (3) freedom of ground water storage from

TABLE 19

CAPITAL AND ANNUAL COSTS
HYDROELECTRIC POWER PROJECTS

Project Unit Structure	Capital Cost	Annual Costs: Capital Recovery	Annual Costs: Operation and Maintenance	Annual Costs: Subtotal	Recreation Facilities	Total Cost
Leavitt Meadow				$ 443,300	$ 57,100	$ 500,400
Leavitt Reservoir	$ 3,134,000	$ 158,100	$ 6,000	164,100		
Leavitt P.D.						
Tunnel	1,292,000	64,500	700	65,200		
Penstock	370,000	22,100	500	22,600		
Powerplant	1,693,000	106,600	55,000	161,600		
Afterbay	589,000	29,700	100	29,800		
Pickel Meadow				1,683,600	61,000	1,744,600
Pickel Reservoir	6,224,000	314,000	10,000	324,000		
Little Walker Div.	312,000	15,600	3,100	18,700		
Antelope P.D.						
Tunnel	14,934,000	746,000	7,400	753,400		
Conduit	3,356,000	200,500	10,100	210,600		
Penstock	669,000	40,000	500	40,500		
Powerplant	2,465,000	155,200	74,800	230,000		
Afterbay	2,106,000	106,200	200	106,400		
Leavitt-Pickel				2,076,500	57,100	2,133,600
Leavitt Reservoir	3,134,000	158,100	6,000	164,100		
Leavitt P.D.						
Tunnel	1,292,000	64,500	600	65,000		
Penstock	370,000	22,100	500	22,600		
Powerplant	1,693,000	106,600	55,000	161,600		
Little Walker Div.	312,000	15,600	3,100	18,700		
Pickel Reservoir	5,823,000	293,800	7,000	300,800		

TABLE 19 (continued)

CAPITAL AND ANNUAL COSTS
HYDROELECTRIC POWER PROJECTS

Project Unit Structure	Capital Cost	Annual Costs: Capital Recovery	Annual Costs: Operation and Maintenance	Annual Costs: Subtotal	Recreation Facilities	Total Cost
Antelope P.D.						
Tunnel	$14,934,000	$ 746,000	$ 7,500	$ 753,500		
Conduit	3,410,000	203,800	10,100	213,900		
Penstock	660,000	39,400	500	39,900		
Powerplant	2,465,000	155,200	74,800	230,000		
Afterbay	2,106,000	106,200	200	106,400		

evaporation losses characteristic of surface reservoirs under normal circumstances; and (4) drainage of waterlogged lands through lowering of ground water tables and reduction of artesian pressure. The disadvantages of ground water development are high cost, possibility of poor quality, and reduction of return flow and "rising ground water" which are presently available to satisfy diversion rights.

Irrigation Wells. The estimated ground water storage capacities of the individual basins are summarized in Table 3. Of these basins, Antelope Valley offers the greatest potential for ground water development. The most logical plan for development of this basin would call for irrigation of a portion of the meadowlands in the center of the valley with wells, and the irrigation of the alluvial aprons at the periphery of the meadowlands with the surface waters which in the past have been used on the meadowlands. This scheme of development would increase the water supply to the alluvial aprons, maintain a full water supply to the center of the valley, drain the present high water table in the center of the valley, and minimize pump lifts and costs.

If the Leavitt Hydroelectric Project were constructed, ground water development costs could be reduced by combining operations with the power project which would supply energy for pumping. The Leavitt powerplant would have an installed capacity of 11,000 kilowatts with a dependable capacity of about 6,600 kilowatts. This means that the powerplant would be operated so that at all times there would be sufficient energy potential for the plant to generate 6,600 kilowatts for the duration of that portion of the load to which it is assigned. During the irrigation season when mandatory water releases are high, the total installed capacity of the powerplant could be used to reduce other power purchases by the utility system or to meet specialized requirements such as pumping loads. If ground water were pumped with energy obtained from the local utility under an exchange agreement, it might be possible to take credit for the irrigation season capacity of the powerplant through an arrangement whereby all or part of the standby charge on the pumps would be waived.

Ground water development costs were estimated in order to permit comparison with possible alternative means of water conservation. The following costs are based on a well field of thirty units with a capacity of two cubic feet per second each, operated continuously for a four-month period each year. The wells would be 100 feet deep and the pump lift would be 70 feet.

The costs assume four percent financing. However, costs would probably be reduced if the project were financed under the Federal Small Reclamation Projects Act of 1956. (70 Stat. 1044; 43 U.S.C. Sec. 422a - 422k, 1958 ed.)

TABLE 20

ESTIMATED COST OF GROUND WATER DEVELOPMENT

	Independent Development	Operation in conjunction with Leavitt Meadow Power Project
Cost per acre-foot per foot of pump lift	$0.04	$0.03
Cost per acre-foot of pumping	2.68	2.08

The presence of boron concentrations in excess of two ppm in water from the artesian zone may preclude development of ground water. However, it may be possible to solve this problem if it should occur, by mixing the poor quality ground water with water withdrawn from the surface ground water zone or with water diverted from the river.

Because of the complex nature of the Antelope Valley ground water basin, the development of irrigation water supplies from this source should be undertaken only under the supervision of a competent ground water geologist or subsequent to a thorough investigation of this basin to determine such factors as specific yield of the valley fill, specific capacity of wells, and the extent of and character of the artesian zone.

The Slinkard Valley Basin could also be served with ground water. As shown by Table 3 the ground water storage capacity in this basin is estimated to approximate

72,000 acre-feet. Existing ground water development for irrigation in Slinkard Valley is the most extensive in the West Walker River Basin. Additional irrigation wells seem to be the only practical means of increasing the available water supply in Slinkard Valley.

It is improbable that irrigation wells with large discharges can be developed in other portions of the West Walker River Basin. However, there are many areas where small amounts of ground water could be pumped for domestic and stock use.

Management of Free Draining Storage Sites. Opportunities exist for increasing the late irrigation season water supply through managment of free-draining ground water storage sites. Water spread on the Lost Cannon Creek ground water basin or the glacial deposits in the Wheeler Hydrographic Unit during flood periods would percolate back to the streams and increase the summer base flow of the stream system. In Antelope Valley, water spread on the east side alluvial apron would contribute to the flow of springs located along the toe of the apron. Many of these springs have been developed by construction of collection ditches, such as the Hot Water and Dragline Ditches. The costs involved could be recovered by taxes and/or water charges from areas benefited by water spreading.

Improvement of Irrigation Efficiency

More and better quality forage could be produced with the quantity of water now being diverted. Three methods could be used to increase the efficiency of irrigation. These methods are improvement of irrigation practices, drainage of high water table areas, and replacement of undesirable phreatophytes. Although these three methods may require an increase in investment and operating costs, the increase may be offset by increased production.

There are a number of state and federal agencies and programs which supply aid and advice on methods of improving water use. The principal agencies which could provide this information are the Mono County Soil Conservation District, the State Division of Soil Conservation, the University of California Agricultural Extension Service, and the U.S. Soil Conservation Service.

Improvement of Irrigation Practice. Wild flooding is the most commonly used method of irrigation in the basin. This method requires a large volume of water in relation to the area irrigated and results in the large surface return flows and large, deep percolation losses.

The border check and controlled flooding methods of irrigation, which are also used in the basin require a smaller irrigation head and reduce the time of application. These or other more efficient irrigation methods could be substituted for wild flooding to increase the irrigation efficiency and thus reduce diversion requirements. Farm improvements required to make better irrigation practices possible would necessarily have to be carried out by the individual ranches.

Adoption of improved methods of irrigation would result in a significant reduction in the amount of water needed for presently wild-flooded irrigated lands. However, the water requirements of the alluvial apron will always be high as compared to other agricultural areas because of the porosity and low water-holding capacity of these soils.

Drainage. Approximately 36 percent of the irrigated lands in Antelope Valley suffer from inadequate drainage. Surface drainage has been attempted in minor ways and in many instances found to be ineffective. The tight, black, silty soils of the meadow pasture area do not drain readily. A second problem which has made surface drains unsatisfactory is the very flat gradient of the valley. Surface drains must be very long in order to use gravity drainage.

Surface drainage has been successful largely in those locations where the drains have intercepted gravel strata interbedded with the silt. Under such circumstances these gravel zones act as collectors for the drainage system. Water in the silt drains vertically into lenses of sand and gravel and then flows through the sand and gravel strata to enter the drain. In contrast, where such a gravel layer is not intercepted, the water must flow horizontally through the almost impervious silt. Under such conditions drains have been observed in which the water was two or more feet below the surface of the ground, yet at a distance of only three or four feet from the edge of the ditch the soil was fully saturated at the surface.

A more expensive, but superior solution to the drainage problem is pumping from sumps or wells which intercept one or more gravel strata. Estimated cost of such pumping over a four-month period is as follows:

Pump lift in feet	Cost per acre-foot per foot or lift	Cost per second-foot over four-month period
5	$ .08	$ 95
10	.05	127
20	.05	216
30	.04	272

The benefits of such a method of drainage are twofold: (1) the water table will be lowered, improving the pasture type, and (2) the drainage water so pumped may be used again for irrigation.

Replacement of Undesirable Phreatophytes. Large amounts of water are consumed by phreatophytes such as willow, rabbit brush, and salt grass throughout the basin. This undesirable vegetation has little, if any, economic value other than to provide shade for livestock and to protect the ground surface from erosion during heavy rainstorms and flood flows in the rivers.

Willows are a nuisance to forming operations and should be controlled. They line the banks of irrigation ditches and have invaded fields. Willow growth presents a hazard to the operation of the ditch system. Trash and twigs are dropped into the ditch, clogging culverts and siphons. Dead roots in the banks rot out leaving holes which may cause piping and washouts. Large acreages of meadowlands have been invaded by willows and the production of forage on these pastures have been impaired. At the same time, consumptive use of water has been increased by the willows.

Rabbit brush and salt grass are to be found in the lower end of Antelope Valley on the dry ridges between sloughs which receive little or no irrigation. In much of this area there is evidence of salts which have been carried to the surface by water rising from the ground water table through capillary action. The phreatophytes draw water from the water table which lies at a depth of several inches to several feet below the surface. Substitution of forage crops such as alfalfa for the existing native vegetation would result in little, if any, increase in evapotranspiration. If crops capable of withdrawing water from the capillary zone were used, it might be necessary to start such crops by flooding or sprinkler irrigation for the first season. Once established, a deep-rooted forage crop should be able to survive on water withdrawn from the capillary zone

Evaluation of Project Alternatives

To justify construction, a water project should satisfy at least the requirements of (1) engineering feasibility, (2) economic justification, and (3) financial feasibility.

A project meets the test of engineering feasibility if:

1. It can be built with available materials and techniques.

2. Sites for the dam, reservoir, and other facilities are geologically and topographically suitable.

3. The proposed structures are sound and functionally sufficient.

4. The water supply is adequate in quantity and quality.

5. The soil and climate are suitable for irrigated agriculture, when this is a project purpose.

In the broad sense, all of the alternatives proposed in this report meet engineering feasibility tests. However, further project refinement would be required in more detailed planning studies and during final design of a particular project feature.

The physical accomplishments of a number of the proposed alternative plans for water development in the West Walker River Basin were evaluated to aid in comparisons between possible projects. Most of the emphasis was placed on the proposed reservoir projects.

The evaluation of project alternatives consisted of two parts, a complex operation study, and a determination of accomplishments for each proposed water storage project. Since this is a reconnaissance type of report, benefits were not evaluated except for flood control benefits which were provided by the U. S. Corps of Engineers. No attempt was made to determine economic justification or financial feasibility.

Operation Studies

In order to determine the accomplishments of the proposed projects, operation studies were made of each of the water storage alternatives to determine irrigation, flood control hydroelectric power, and recreational accomplishments. The 35-year interval from October 1, 1920, to September 30, 1955, was chosen as the period of study.

In the first phase of the operation study, each reservoir was operated to satisfy water demands for fishery maintenance and enhancement, irrigation, flood control, and hydroelectric power production insofar as these were project purposes. The demands for water for project purposes are summarized in Table 21 for each of the reservoirs under consideration. Maximum reservoir storages were reduced during the period from November 1 to March 31, to provide space for rain flood control when this was a project purpose. Streamflow fishery maintenance water requirements were obtained from the California Department of Fish and Game.

TABLE 21

RESERVOIR EVAPORATION AND RELEASE SCHEDULE*

(Quantities in Acre-Feet)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mountain Lake Projects													
Helen Lake Releases													
Streamflow Maint.**	20	20	20	20	20	20	20	20	20	20	20	20	240
Irrigation	0	0	0	0	0	0	20	50	20	10	0	0	100
Total	20	20	20	20	20	20	40	70	40	30	20	20	340
Harriet Lake Releases													
Streamflow Maint.	30	30	30	30	30	30	30	30	30	30	30	30	360
Irrigation	0	0	0	0	0	0	0	20	10	10	0	0	40
Total	30	30	30	30	30	30	30	50	40	40	30	30	400
Ruth Lake Releases													
Streamflow Maint.	10	10	10	10	10	10	10	10	10	10	10	10	120
Irrigation	0	0	0	0	0	0	0	10	10	10	0	0	30
Total	10	10	10	10	10	10	10	20	20	20	10	10	150
Bonnie Lake Releases													
Streamflow Maint.	20	20	20	20	20	20	20	20	20	20	20	20	240
Irrigation	0	0	0	0	0	0	20	50	20	10	0	0	100
Total	20	20	20	20	20	20	40	70	40	30	20	20	340
Fremont Lake Releases													
Streamflow Maint.	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishery Enhancement	10	10	10	10	10	10	0	0	0	0	0	10	70
Irrigation	0	0	0	0	0	0	30	130	70	50	30	0	310
Total	10	10	10	10	10	10	30	130	70	50	30	10	380
Lane Lake Releases													
Streamflow Maint.	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishery Enhancement	10	10	10	10	10	10	0	0	0	0	0	10	70
Irrigation	0	0	0	0	0	0	20	60	40	30	20	0	170
Total	10	10	10	10	10	10	20	60	40	30	20	10	240
Leavitt Lake Releases													
Streamflow Maint.	10	10	10	10	10	10	10	10	10	10	10	10	120
Irrigation	0	0	0	0	0	0	100	470	220	100	0	0	890
Total	10	10	10	10	10	10	110	480	230	110	10	10	1,010

TABLE 21 (continued)

RESERVOIR EVAPORATION AND RELEASE SCHEDULE

(Quantities in Acre-Feet)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Irrigation Projects													
Roolane Reservoir Releases													
Streamflow Maint.	1,230	1,110	1,230	1,190	2,460	2,380	2,460	2,460	1,190	1,230	1,190	1,230	19,360
Irrigation	0	0	0	7,700	15,400	14,800	16,600	11,700	6,500	0	0	0	72,700
Total	1,230	1,110	1,230	8,890	17,860	17,180	19,060	14,160	7,690	1,230	1,190	1,230	92,060
Leavitt Meadow Releases													
Streamflow Maint.	1,230	1,110	1,230	1,190	2,460	2,380	2,460	2,460	1,190	1,230	1,190	1,230	19,360
Irrigation	0	0	0	7,700	15,400	14,800	16,600	11,700	6,500	0	0	0	72,700
Total	1,230	1,110	1,230	8,890	17,860	17,180	19,060	14,160	7,690	1,230	1,190	1,230	92,060
Hydroelectric Power Projects													
Leavitt Meadow													
Evaporation (af/a)	0.01	0.02	0.05	0.08	0.13	0.15	0.20	0.20	0.13	0.06	0.04	0.02	1.09
Releases													
Streamflow Maint.	930	840	930	900	1,860	1,800	1,860	1,860	900	930	900	930	14,640
Min. Irrig. & Power	3,070	2,780	3,070	2,980	2,770	2,680	2,770	2,770	2,980	3,070	2,980	3,070	34,990
Irrigation	0	0	0	3,200	10,750	10,300	11,950	7,050	2.000	0	0	0	45,250
Total	4,000	3,620	4,000	7,080	15,380	14,780	16,580	11,680	5,880	4,000	3,880	4,000	94,880
Pickel Meadow													
Evaporation (af/a)	0.02	0.03	0.07	0.12	0.19	0.23	0.29	0.29	0.19	0.10	0.06	0.03	1.62
Releases													
Streamflow Maint.	1,860	1,680	1,860	1,800	3,660	3,600	3,660	3,660	1,800	1,860	1,800	1,860	29,100
Min. Irrig. & Power	3,690	3,330	3,690	3,570	3,690	3,570	3,690	3,690	3,570	3,690	3,570	3,690	43,440
Irrigation	0	0	0	2,330	8,050	7,630	9,250	4,350	1,130	0	0	0	32,740
Total	5,550	5,010	5,500	7,700	15,400	14,800	16,600	11,700	6,500	5,550	5,370	5,550	105,280
Leavitt-Pickel													
Evaporation (af/a)	0.02	0.03	0.07	0.12	0.19	0.23	0.29	0.29	0.19	0.10	0.06	0.03	1.62
Releases													
Streamflow Maint.	1,860	1,680	1,860	1,800	3,660	3,600	3,660	3,660	1,800	1,860	1,800	1,860	29,100
Min. Irrig. & Power	1,540	1,390	1,540	1,490	3,380	3,270	3,380	3,380	1,490	1,540	1,490	1,540	25,430
Irrigation	0	0	0	4,410	8,360	7,930	9,560	4,660	3,210	0	0	0	38,130
Total	3,400	3,070	3,400	7,700	15,400	14,800	16,600	11,700	6,500	3,400	3,290	3,400	92,660

* Evaporation applies to hydroelectric projects only. Values for evaporation are the estimated difference between gross reservoir evaporation and average evapotranspiration of native vegetation and/or evaporation from natural water surfaces within the proposed reservoir and are measured in acre-feet per acre of reservoir surface.

**Streamflow maintenance requirement is the stated quantity or historical flow, whichever is less.

The water supply for reservoir operation was estimated as the historical streamflow at the damsite adjusted for irrigation within the reservoir area. In addition, adjustments were made for upstream reservoirs and diversions from other streams when these facilities were part of the project under consideration.

In years when the water supply was insufficient to meet the demands shown on Table 21, water requirements were satisfied in the following order: (1) fishery maintenance, (2) hydroelectric power with minimum irrigation, and (3) irrigation. Water released for irrigation was limited to monthly quantities which would not deplete the reservoir storage to an amount less than certain predetermined first-of-the-month values. This permitted the water supply in drought years to be spread over the entire irrigation season instead of being exhausted in the spring.

The second phase of the operation studies attempted to determine how the water released from upstream storage reservoirs could be used to the best advantage in the Antelope Valley area without infringing on historical Nevada entitlements. Therefore, diversions in Antelope Valley were not limited to amounts provided for under Decree C-125.

In this second phase the watershed between the Antelope Gage at the head of Antelope Valley and the Hoye Gage in Nevada was treated as a single hydrographic unit. A hydrologic equation, containing elements of inflow, evapotranspiration, outflow, and storage, was solved by successive approximation to establish monthly storage changes and evapotranspiration in the unit. Inflow was computed as the estimated historical flow at the Antelope Gage, taking into account impairment due to project reservoir operation computed in the preceding phase of the operation study plus estimated runoff from the valley floor and surrounding hills. Storage within the hydrographic unit consisted of 29,130 acre-feet of free-draining underground storage in the valley fill and 57,580 acre-feet of active storage in Topaz Lake. Evapotranspiration losses included evaporation from water surfaces, including Topaz Lake. Outflow from the hydrographic unit was taken as the discharge at the Hoye Gage.

In this portion of the study, advantage was taken of the natural ground water storage in the alluvial apron of Antelope Valley by recharging with surplus snowmelt water in the spring. The free-draining ground water storage was treated as an offstream reservoir. Inflow into ground water storage was estimated to be 34 percent of the sum of local runoff and diversions from the West Walker River. Outflow was estimated as 15 percent of beginning-of-the-month storage.

Topaz Reservoir was operated to supply the needs of Nevada, which were estimated to be 125,710 acre-feet per year at Hoye Canyon. This estimate of Nevada requirements was determined by deducting the average annual spill at the Indian Diversion Dam near Schurz, Nevada, during the irrigation season, from the estimated average annual discharge at the Hoye Bridge Gage during the period 1947 to 1956. Spills at the Indian Diversion Dam, from which the last diversion on the river is made, may be considered surplus water. This period was somewhat wetter than normal, with the annual runoff of the Walker River 12 percent greater than long-term average. Diversions to offstream storage in Topaz Lake were limited to 49,000 acre-feet per month, storage to an active reservoir capacity of 57,580 acre-feet, and annual releases to 125,710 acre-feet. Table 22 summarizes the monthly release schedule for Topaz Reservoir which, in conjunction with streamflows of the Walker River, would satisfy Nevada rights.

The amount of water developed in excess of Nevada entitlements is available for diversion in the Antelope Valley Hydrographic Unit. This water can be diverted according to the schedule shown in Table 22. This schedule allows the maximum diversion possible without interfering with fishery needs (10 second-feet past all diversion points) and the entitlement of Nevada users. The diversion schedule shown is compiled from maximum monthly diversions recorded by the Antelope Valley Mutual Water Company and reflects present irrigation practice rather than the more ideal requirements shown in Table 13. It was assumed that present practices

TABLE 22

MONTHLY SCHEDULES FOR OPERATION STUDIES OF PROJECT SERVICE AREA AND TOPAZ RESERVOIR

(Quantities in acre-feet except as noted)

Month	Antelope Valley			Topaz Reservoir	
	Stream flow maint.	Maximum evapo-transpiration loss	Maximum diversions	Unit evap. (AF/AC)	Maximum releases
Oct.	620	1,250	3,070	0.29	6,620
Nov.	600	1,330	1,190	0.17	1,190
Dec.	620	670	1,230	0.09	1,230
Jan.	620	420	1,230	0.07	1,230
Feb.	560	620	1,110	0.09	1,110
March	620	970	3,070	0.20	1,230
April	600	3,880	8,890	0.34	11,620
May	620	8,710	17,860	0.47	21,910
June	600	11,080	19,780	0.57	22,990
July	620	11,270	19,060	0.71	24,090
August	620	8,450	14,160	0.65	19,700
Sept.	600	5,750	9,160	0.48	12,790
TOTAL	7,300	54,400	99,810	4.13	125,710

Unit evaporation given in acre-feet per acre of reservoir surface.

would continue because the proposed projects do not provide a full water supply and it is desirable to use the natural underground regulatory storage as much as possible.

A third phase of the operation study evaluated the power production potential of each of the hydroelectric power project alternatives as if the project had been in operation during the 35-year period from 1920 to 1955. The total computed outflow determined in the first phase of the operation study for each reservoir was analyzed to determine the amount of energy that could have been generated each month without exceeding the hydraulic capacity of the power facilities or infringing on streamflow requirements below the dam and below the confluence of the West Walker and Little Walker Rivers. These limitations are summarized below for each project alternative:

Project Item	Leavitt	Pickel	Leavitt-Pickel Pickel Unit
Hydraulic Capacity in cfs	406	300	300
Streamflow Maintenance Requirement in cfs			
Below Dam:			
May-August	30	60	60
Sept.-April	15	30	30
Below Little Walker:			
May-August	-	40	40
Sept.-April	-	10	10

Using these flow limitations, the hydroelectric energy which could be produced by each of the three alternative power projects was determined. The potential amount of energy was computed as 0.829 kilowatt-hours per acre-foot per foot of head.

Evaluation of Project Accomplishments

Accomplishments of the proposed alternative projects heretofore described would accrue from flood control, production of hydroelectric power, new or regulated irrigation water, and new recreational opportunities. Dollar values were estimated for flood control by the U. S. Corps of Engineers, but a similar evaluation for the other accomplishments was beyond the scope of this report.

Flood Control. Floods originating largely in the California portion of the stream system cause damage throughout the entire basin. Therefore, flood control should be a major consideration of any surface storage projects to be constructed in the Walker River watershed.

Of the two general classifications of floods, winter rains cause most of the flood damage in California. Floods from snowmelt, which are of minor importance in California, are the greatest cause of flood damage in Nevada.

Sacramento District, U. S. Corps of Engineers, estimated the annual flood damages and benefits which would accrue from flood control storage on the Walker River. The estimate, which is of a preliminary nature, is shown in Table 23.

TABLE 23

SUMMARY OF ANNUAL FLOOD DAMAGES AND ANNUAL FLOOD CONTROL BENEFITS ACCRUING FROM STORAGE ON WALKER RIVER

(1957 Price Level)

Location	Rain floods	Snowmelt floods	Total rain and snowmelt floods
	ANNUAL DAMAGES		
West Walker River Pickel Meadows to Topaz Lake, California	$ 20,800	$ 15,900	$ 36,700
West Walker River Topaz Lake to Junction with East Walker River, Nevada	2,200	3,600	5,800
Main Walker River Mason Valley, Nevada	15,100	22,000	37,100
Main Walker River Walker Reservoir to Walker Lake, Nevada	Negligible	8,000	8,000
TOTAL	$ 38,100	$ 49,500	$ 87,600

TABLE 23 (continued)

SUMMARY OF ANNUAL FLOOD DAMAGES AND ANNUAL FLOOD CONTROL BENEFITS ACCRUING FROM STORAGE ON WALKER RIVER

(1957 Price Level)

Location	Rain floods	Snowmelt floods	Total rain and snowmelt floods
	ANNUAL BENEFITS		
Estimated benefits with 20,000 acre-feet of rain flood reservation (November 1 - April 1) and 160,000 acre-feet of snowmelt reservation on West Walker River	$ 32,000*	$ 42,000*	$ 74,000*
Benefits per acre-foot of flood control reservation	1.60	0.26	

*Preventable damages are estimated to be 85 percent of total damages.

Data collected following the 1950 and 1955 rain floods are included in the estimate.

For the purposes of this report, the annual flood control benefits of the proposed projects were limited to $1.60 per acre-foot of rain flood reservation. No attempt to control snowmelt floods by reservation of storage space was contemplated. Control of such floods would result in relatively small benefits in California in comparison to the potential loss in project revenues which would be suffered by reduction of available water conservation space and hydroelectric power production. The projects were operated to provide a flood control reservation during the period November 1 to April 1. Annual flood control benefits which could be derived from possible projects considered in this investigation are summarized in Table 24.

TABLE 24

ANNUAL FLOOD CONTROL BENEFITS

	Rain flood reservation in acre-feet	Annual reduction in flood damages
Irrigation Projects		
Roolane 9M (9,000 AF)	9,000	$ 14,400
Roolane 18M (18,000 AF)	14,000	22,400
Roolane 26M (26,000 AF)	14,000	22,400
Leavitt Meadow	14,000	22,400
Hydroelectric Projects		
Leavitt Meadow	7,500	12,000
Pickel Meadow	10,000	16,000
Leavitt-Pickel	12,500	20,000

Power. Hydroelectric energy developed by the projects proposed in this report could be most logically marketed through the Sierra Pacific Power Company system which serves western Nevada and a portion of eastern California, including the Antelope Valley area.

In 1960 the Sierra Pacific Power Company system had a capacity of 9,400 kilowatts provided by 5 small hydroelectric plants and 1,034 kilowatts supplied by engine-driven generators. In addition, the company purchases considerable power, mostly from the Pacific Gas and Electric Company. In 1960, the power requirement of the Sierra Pacific Power Company was 688,337,000 kilowatt hours with a peak load of 125,570 kilowatts. The peak demand occurred in December. The peak demand of Sierra Pacific on the Pacific Gas and Electric Company for the year was 106,470 kilowatts and also occurred in December. Imported power is supplied by three transmission lines over Donner Pass. The peak demand on these transmission facilities approaches their capacity.

The Sierra Pacific system load growth in recent years (1950 through 1960) has increased at a compound annual growth rate of about 10 percent for capacity and 11 percent for energy. Assuming that the power load will continue to increase during the next 10-year period at the same rate as during the 1950-1960 period, the 1970 peak power demand will be 325,700 kilowatts and the annual energy requirement will be 1,954,000,000 kilowatt-hours. This represents an increase of about 200,000 kilowatts and 1,266,000,000 kilowatt, hours, respectively over the 1960 figures.

The increase in the power load, as indicated above, is greater than the combined capacity of the power projects which are proposed for near-future construction in the Sierra Pacific Power Company service area. The proposed projects are as follows:

Prime mover	Installed capacity (kilowatts)	Location	System
Diesel	8,000	East of Carson City	Sierra Pacific
Gas turbine	12,000	East of Sparks	Sierra Pacific
Gas turbine	12,000	East of Sparks	Sierra Pacific
Diesel	8,000	Not determined	Sierra Pacific
Thermal	44,000	East of Sparks	Sierra Pacific
Hydro	28,000	Washoe Project	USBR
Hydro	33,000	Walker River	Unknown
TOTAL	145,000		

Although detailed studies of system power loads and the existing and future power resources, including their relationship to system operations, would be required to determine the usable peaking capacity of the proposed Walker River powerplants, it is probable that the output of the plants could be absorbed advantageously into the Sierra Pacific power system.

The Leavitt and Antelope power developments were planned for operation at an annual dry-year capacity factor of about 20 percent. Due to the peaking limitations of a number of the power resources there appears to be a current need for this peaking capacity. Operation of the Walker River plants to meet peak loads would permit a reduction in the peak demands on the Donner Pass transmission lines, thereby increasing the load factor on the lines and resulting in a lower cost per kilowatt-hour for the power imported from California.

Potential power production of the projects proposed herein was estimated as follows:

Project	Average Annual Power Production in Kilowatt Hours	Dependable Capacity in Kilowatts
Leavitt	26,545,000	6,640
Pickel	72,344,000	20,420
Leavitt-Pickel	98,695,000	15,250

Irrigation. The economy of the Antelope Valley area presently rests primarily upon the marketing of livestock, principally beef calves. Cattle are pastured on the high mountain ranges during the summer while hay is produced on the irrigated lands. In the fall, the animals are returned to the valley to graze off whatever pasture is available on the irrigated lands. Calves are marketed at a live-weight between 450 and 550 pounds during the period October 15 to December 1, depending mainly upon the availability of feed. The availability of feed, in turn, is governed by the availability of water during the latter part of the irrigation season. Hay carryover is essential for feeding of the breeding stock that is retained in the valley during the winter.

Each of the proposals for project development on the West Walker River would extend the irrigation season in Antelope Valley by storing water that otherwise is largely wasted during the spring runoff. This water would be available for use in late summer thereby permitting more feed to be produced than at present. Increased income from beef production would result as calves could be marketed about 2 months older and at least 60 pounds heavier than at present with little increase in cost except for project water service.

The chief direct irrigation accomplishment would be the application of additional water to the 11,000 acres of land now receiving water in Antelope Valley. The projected cropping patterns for the 11,000 acres, after application of water, were distributed in the same proportion as the probable cropping patterns shown in Table 9. The average seasonal increases in diversions and evapotranspiration under project conditions provide a measure of the potential irrigation accomplishments to be derived from the projects. Since crop production is more closely related to consumptive use than to diversions, the estimated increase in evapotranspiration is the best measure of accomplishments in California. Total project yield was computed as the sum of Antelope Valley evapotranspiration and Hoye Canyon water supply. The opportunity for use and reuse of the latter item in Smith, Mason, and Walker Lake Valleys in Nevada makes the flow at Hoye Canyon comparable to consumptive use. A summary of project irrigation accomplishments is presented in Table 25.

Present operating practices of Topaz Reservoir were modified to yield the best overall balance of water use and to take full advantage of the free-draining ground water storage in Antelope Valley. The irrigation accomplishments shown in Table 25 reflect this modified operating procedure.

Recreation. The annual migration of people from Southern California to the West Walker River Basin seeking recreation has been increasing each year for the past several years. The ever increasing demand for recreation would result in full development of the recreational potential of

TABLE 25

ANNUAL YIELD OF IRRIGATION WATER

(Quantities in acre-feet)

Project	California		Nevada	Total project yield
	Diversion	Evapo-transpiration	Water supply at Hoye Canyon	
Mountain Lake Projects				
Helen Lake	630	10	830	840
Harriet Lake	610	0	830	830
Ruth Lake	610	0	830	830
Bonnie Lake	630	10	830	840
Fremont Lake	800	100	810	910
Lane Lake	680	40	830	870
Leavitt Lake	1,260	370	760	1,130
Irrigation Projects				
Roolane 9M	4,850	2,740	710	3,450
Roolane 18M	7,220	3,480	1,210	4,690
Roolane 26M	9,090	4,190	1,410	5,600
Leavitt Meadow (Irrigation)	9,090	4,190	1,410	5,600
Hydroelectric Power Projects				
Leavitt Meadow (Power)	5,780	3,030	670	3,700
Pickel Meadow	9,850	5,900	-1,090	4,810
Leavitt-Pickel	12,310	6,090	-1,430	4,660

any of the proposed reservoirs in the West Walker River area within 50 years.

The major recreation pursuit in the basin at the present time is sport fishing. The sport fishery of the West Walker River is almost exclusively a trout fishery. It is supported largely by planted, catchable-sized rainbow trout although some natural production exists.

Construction of surface water storage projects would make profound changes in the recreational potential of the area through substitution of reservoirs for natural stream and meadow areas and modification of the natural flow of the stream system. These changes would principally affect sport fishing and aquatic sports. Reduction of range area for game should have only a slight effect on hunting. It is imperative, therefore, that planning studies consider the effect of the surface water storage alternatives on recreation.

Of the mountain lake storage projects, only Leavitt Lake was evaluated for recreation in terms of visitor-days with and without the project. Leavitt Lake is about 7 miles southwest of Leavitt Meadows and is accessible from State Highway 108 by a forest road. An area of 70 acres on the north side of the lake contains a modestly sparse stand of pines and is suitable for recreation. The scenery around the lake is strikingly rugged. However, when evaluated in terms of visitor-days, the Leavitt Lake Project was found to be detrimental to recreation because of the fluctuation of the reservoir water level.

Water conservation at the Fremont, Ruth, Harriet, Helen, and Bonnie Lake sites would also reduce the recreational potential of these lakes. The reduction would be especially severe at Fremont Lake. Without reservoir development, Fremont Lake would support extensive recreational development and use consistent with its remote location and elevation of more than 8,200 feet. Neither the present nor the future recreational use has been quantitatively estimated for these five small, high lakes.

Reservoir development at the Roolane, Leavitt Meadow, and Pickel Meadow sites would have recreational significance. Future recreational use at these reservoirs was estimated on the basis of (1) the land available for recreational development at each site, (2) the relative attractiveness of the sites, and (3) the distance from population centers. Fluctuation of the reservoir water level also has an adverse effect on recreational use at reservoirs. However, it was assumed that since the greatest fluctuation would be experienced at the most attractive site and the least fluctuation be experienced at the least attractive site, attractiveness of the surroundings would balance the reservoir fluctuation. Therefore, no differentiation was made in the recreational use per acre of developable land.

Net developable recreational areas around the alternative reservoir sites range in size from 40 to 77 acres. Additional areas are available and at some remote date may be used. Therefore, for convenience, a standard area of 75 acres was applied to each of the alternatives in estimating future recreational use.

There was considerable difference in attractiveness of the three major sites. Roolane, the most attractive, is rimmed by steep, wooded mountains and massive outcroppings of rock. However, the existing two lakes and two ponds in the reservoir area would be inundated.

The Leavitt Meadow site is almost as attractive as the Roolane. It is more accessible because of the lower elevation and proximity to U.S. Highway 395. The western side is faced by an escarpment looming 1,400 feet above the reservoir with pine groves and mixed conifers and hardwoods. The eastern site near the damsite is hilly with a sparse cover of sagebrush and juniper. Farther south the hills are steeper and assume a more wooded aspect with pines, mixed conifers, and hardwoods predominating.

Pickel Meadow is the least attractive of the three major sites. The hills toward the north and southeast are sparsely covered by sagebrush and juniper with pine groves at some distance. The escarpment which bounds the west side of the reservoir rises 200 to 400 feet and is topped by pines at higher elevations near the south end of Pickel Meadow.

The third item entering into the evaluation of recreation was the distance from population centers. Recreational use by people from metropolitan centers is limited by the overnight lodging available. Overnight lodging can be provided in campgrounds, summer homes, or commercial establishments. People who live in the vicinity or who stay at accommodations at some distance from the reservoir will not require overnight lodging. However, in 1960, this latter group represented only a small portion of the recreation users in the West Walker River area. Therefore, it was assumed that the day use of this latter group will continue to be small and can be overlooked in this preliminary study.

The recreational use to be expected initially and after 50 years has been estimated in terms of visitor-days with and without the reservoir for each of the three major proposed storage reservoir projects and is shown in Table 26. The estimate for Leavitt Lake is also shown on this table. The year 1960 was used as a base.

Project Financing

The costs of construction and operation of projects in the West Walker River Basin in California are high in relation to the somewhat limited benefits to be derived. Therefore, projects generally must be financed at the lowest interest rate obtainable in order to be feasible.

TABLE 26

ANNUAL RECREATION USE OF PROPOSED RESERVOIRS

Reservoir	Leavitt Lake	Roolane 26M	Leavitt Meadow	Pickel Meadow
Annual Recreation Use in Visitor-Days				
1960	6,000	13,000	17,000	25,000
Without project 50th year	18,000	40,000	50,000	75,000
With project, initial year	3,000	24,000	24,000	35,000
With project 50th year	9,000	144,000	144,000	144,000
Net Recreation Use Due to Project in Visitor-Days				
Initial year	-3,000	11,000	7,000	10,000
50th year	-9,000	104,000	94,000	69,000

The most economical financing may be achieved by formation of local public districts to either construct a project or to contract with the United States or the State of California for construction.

In the event that a local district elects to construct the project, it might obtain financing by either (1) district general obligation bonds, (2) state financial assistance under the California Davis-Grunsky Act

Program (Water Code Section 12880 - 12891.1) or (3) from a federal loan under the Small Reclamation Projects Act. (70 Stat. 1044, 43 U.S.C., Sec. 422a - 422k, 1958 ed.)

The Davis-Grunsky Act provides state financial assistance for the investigation and construction of small water conservation projects through grants and loans to public agencies. Grants may be made for fish and wildlife enhancement, recreational purposes, and for initial water supply and sanitary facilities in which there is a statewide interest. Loans can be made for projects which local public agencies are otherwise unable to finance.

The Small Reclamation Project Act provides for the loan of up to 5 million dollars for the construction of a project with a total cost of not more than 10 million dollars. The loan must be repaid within 50 years. Interest must be paid on the portion of the loan allocated to purposes other than irrigation or upon lands in excess of the acreage limitations imposed by the act.

Financial feasibility to a large extent will depend upon the rate of interest applicable and the functions against which interest is charged. The total interest charge depends upon the program under which the work is financed. Under the Davis-Grunsky Act, the rate of interest is that which is paid on the general obligation bonds of the State of California during designated periods preceding the time of application for a loan (Water Code Section 12884). Under the Small Reclamation Projects Act, interest would be paid on the portion of the project costs allocated to power and municipal water service; irrigation costs would be interest free for non-excess lands.

CHAPTER VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The area of investigation is located in the California portion of the West Walker River Basin in northern Mono County and extends generally from the northern boundary of Yosemite National Park on the south to Topaz Lake on the California-Nevada state line on the north. Economy of the area is based primarily on livestock and recreation.

Chronic irrigation deficiencies occur even in years of average water supply. These deficiencies usually occur in the latter part of the irrigation season but begin as early as June in years of subnormal streamflow.

Average seasonal flow of the West Walker River at the head of Antelope Valley, the principal agricultural area in the West Walker River Basin in California, is 190,200 acre-feet. Seasonal streamflow has varied from a maximum of 372,700 acre-feet to a minimum of 67,900 acre-feet.

The potential water requirements of lands in both the California and Nevada portions of the watershed exceed the available water supply. Controversies over the use of water have been almost continuous since the turn of the century. Decree C-125 of the Federal District Court of Nevada, entered in the case of United States v. Walker River Irrigation District, et al, Equity No. C-125, on

April 14, 1936, defines the rights to the use of water from the Walker River stream system for irrigation. There are about 138,000 acres of land in the entire Walker River Basin for which water rights are claimed. The potential consumptive use on these lands exceeds the average annual runoff of the basin. Defined rights for lands within the area of investigation total 292 second-feet for irrigation of 18,300 acres. Land classification and use surveys made in 1955 and 1956 determined that of a potential irrigable area of 25,700 acres in California, 16,490 acres were irrigated.

The mineral quality of water in the region is generally good. The major exceptions are the waters from hot springs associated with the numerous faults of the area and the artesian ground water zone in Antelope Valley. Waters from these sources contain boron, fluoride, and arsenic in sufficient concentrations to be deleterious to plant and animal life.

Means of improving the local water supply considered in the preparation of this report included (1) construction of surface storage reservoirs at Leavitt Meadow, Pickel Meadow, and Roolane Reservoir sites and seven mountain lakes; (2) utilization of ground water; and (3) improvement of irrigation efficiency.

The continuing problems of distribution and development of the waters of interstate streams has led to the creation of interstate compact commissions by California and

Nevada. These commissions are now engaged in the negotiation of a compact to apportion the waters of Lake Tahoe and the Truckee, Carson, and Walker River Basins between the two states. The terms of the compact may determine to what extent the water resources of the West Walker River may be developed for the benefit of California.

Conclusions

1. There is an apparent shortage of irrigation water supply to presently irrigated lands during the latter part of the irrigation season in years of normal supply, and beginning in early summer in years of subnormal streamflow.

2. Economic factors and the limitation in the amount of available water appear to preclude any significant increase in irrigated area, and may generally restrict future development to residential and recreational uses.

3. Additional water supplies could be obtained by one or more of the following: construction of surface reservoir storage, development of ground water supplies, and more efficient irrigation practices.

4. On the basis of project yield, construction of reservoirs at the Roolane, Leavitt Meadow, and Pickel Meadow sites and ground water development offer the greatest potential for future water conservation. These reservoirs could provide significant flood control and recreational benefits.

Recommendations

As a result of the findings of this investigation, it is recommended that:

1. Further investigations of surface reservoir projects in this area be limited to the Roolane, Pickel Meadow, and Leavitt Meadow Reservoir sites.

2. Further investigations be made of the possible use of ground water storage.

B I B L I O G R A P H Y

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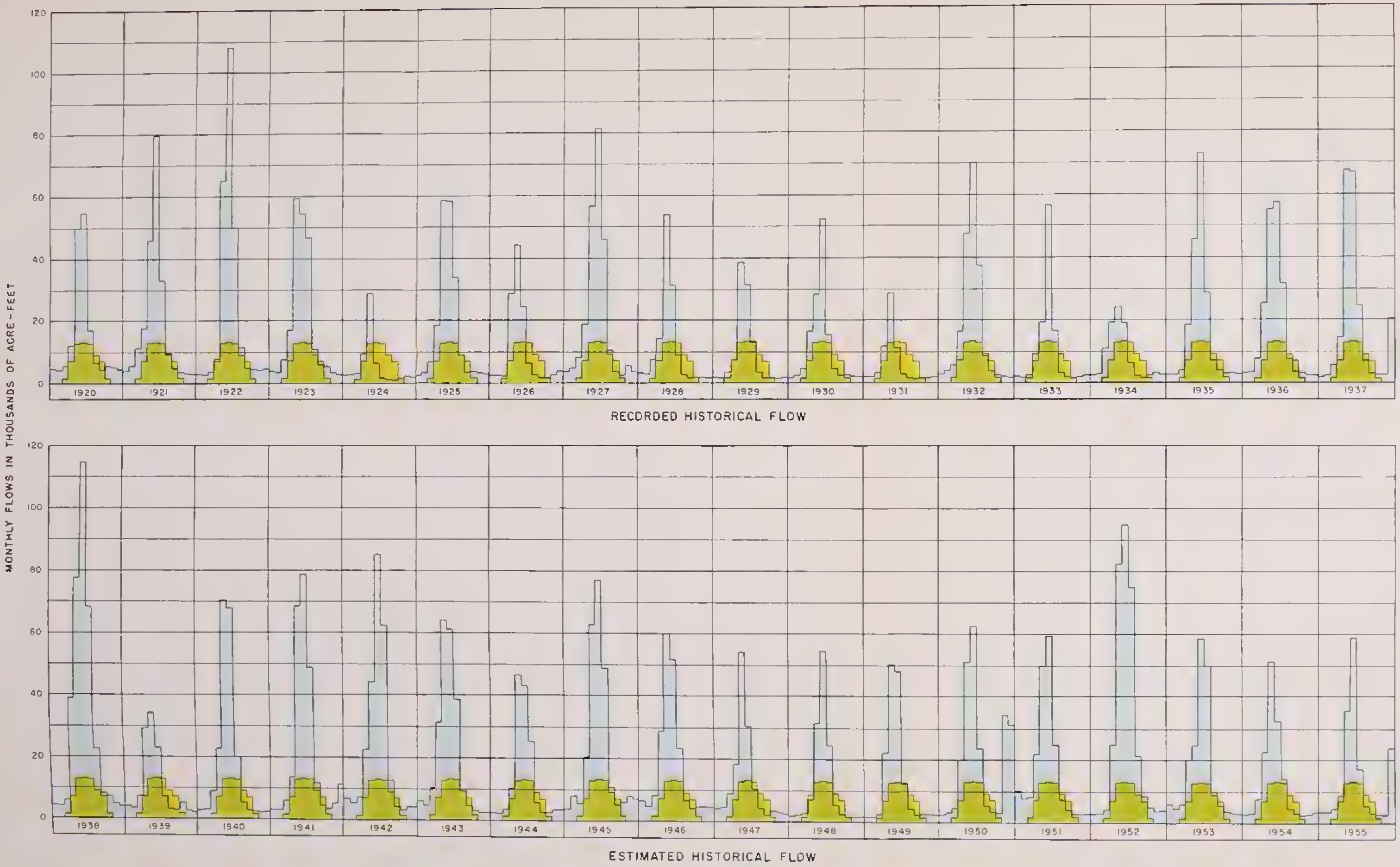
LEGEND
LINES OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES, 1897-98 THROUGH 1946-47
ACTIVE - PRECIPITATION STATION
INACTIVE
STREAM GAGING STATION WITH ESTIMATED AVERAGE SEASONAL STREAMFLOW IN ACRE-FEET FOR PERIOD 1920-21 THROUGH 1954-55
INACTIVE
LOCATION OF AREA OF INVESTIGATION
OREGON
NEVADA
PACIFIC OCEAN
MEXICO
INVESTIGATED AREA
NEVADA
CALIFORNIA
DOUGLAS CO.
MONO CO.
ALPINE CO.
Hoye Bridge
TOPAZ LAKE
ANTELOPE VALLEY
HIGH LINE DITCH
ALKALI DITCH
ANTELOPE GAGE 190,200
JUNCTION GAGE 170,100
West Walker River
Little Walker River
Molybdenite
Mill Canyon
Little Antelope Valley
Slinkard Cr
Cottonwood Cr
Rock Cr
SLINKARD HYDROGRAPHIC UNIT
ANTELOPE HYDROGRAPHIC UNIT
LOST CANNON HYDROGRAPHIC UNIT
WHEELER
PICKEL HYDROGRAPHIC UNIT
SONORA PASS
T.9 N.
T.8 N.
T.7 N.
T.6 N.
T.5 N.
R.22 E.
R.23 E.
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
WEST WALKER RIVER INVESTIGATION
AREA OF INVESTIGATION
AND
DISTRIBUTION OF PRECIPITATION AND RUNOFF
SCALE OF MILES



LEGEND

NOTE

IDEAL IRRIGATION REQUIRMENT IS THE DIVERSION DEMAND ON THE WEST WALKER RIVER REQUIRED TO MEET THE POTENTIAL CONSUMPTIVE USE ON ALL IRRIGABLE LANDS UNDER THE EXISTING DITCH SYSTEM IN THE CALIFORNIA PORTION OF ANTELOPE VALLEY

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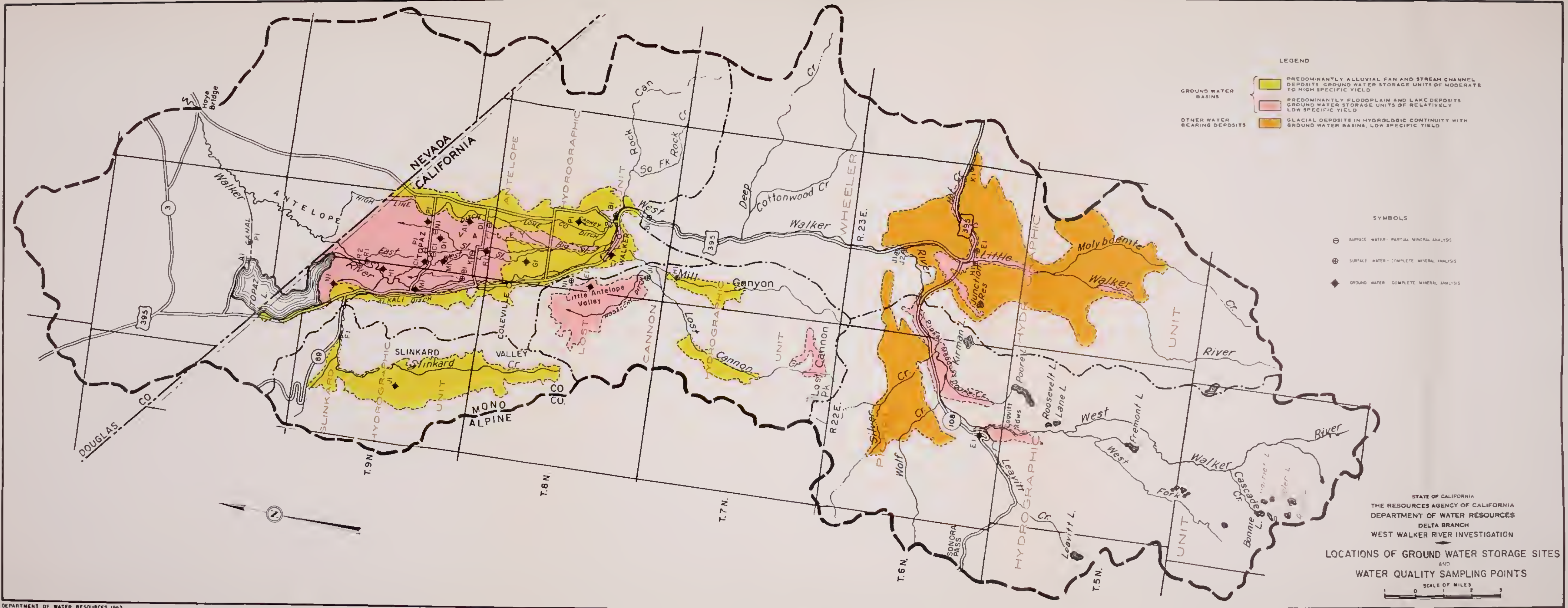
WEST WALKER RIVER INVESTIGATION

HISTORICAL FLOW OF THE
WEST WALKER RIVER AT HEAD
OF ANTELOPE VALLEY
AND
IRRIGATION DEMAND THEREON IN CALIFORNIA



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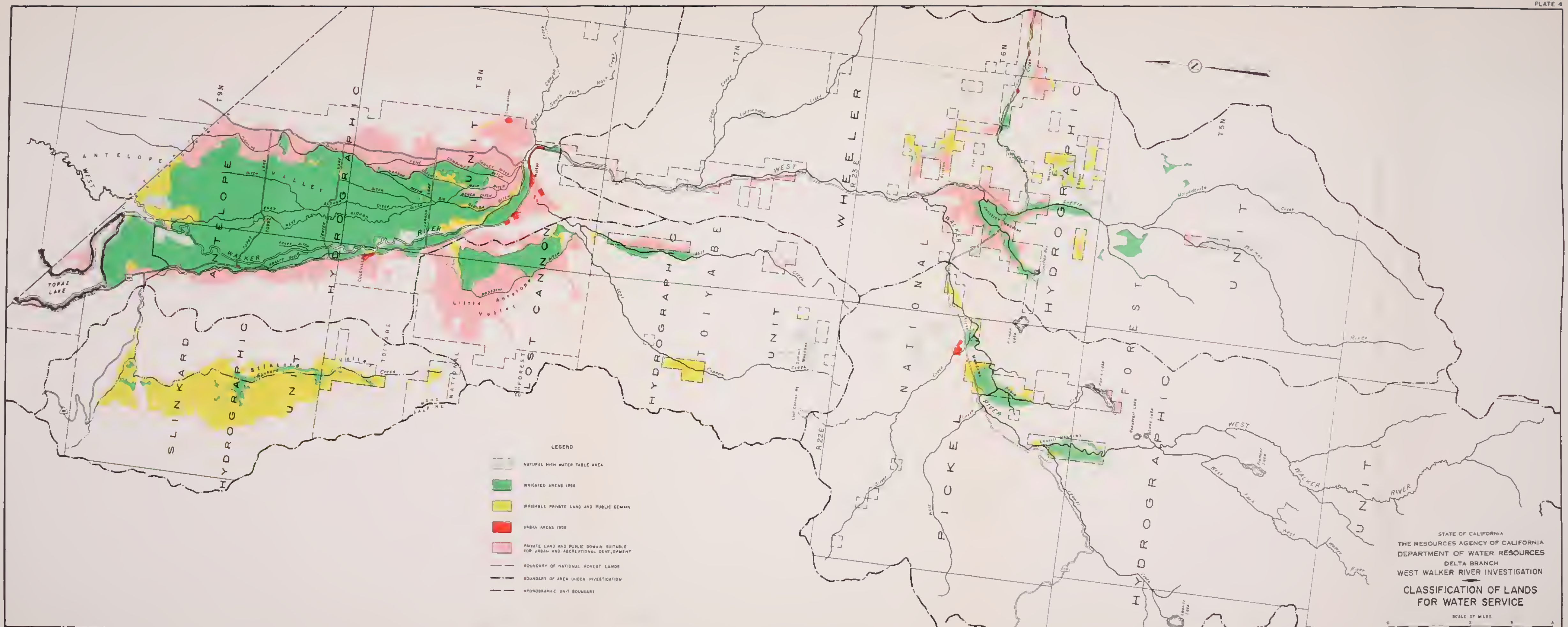
WEST WALKER RIVER INVESTIGATION

LOCATIONS OF GROUND WATER STORAGE SITES
AND
WATER QUALITY SAMPLING POINTS

SCALE OF MILES
1 0 1 2 3

DEPARTMENT OF WATER RESOURCES 1963



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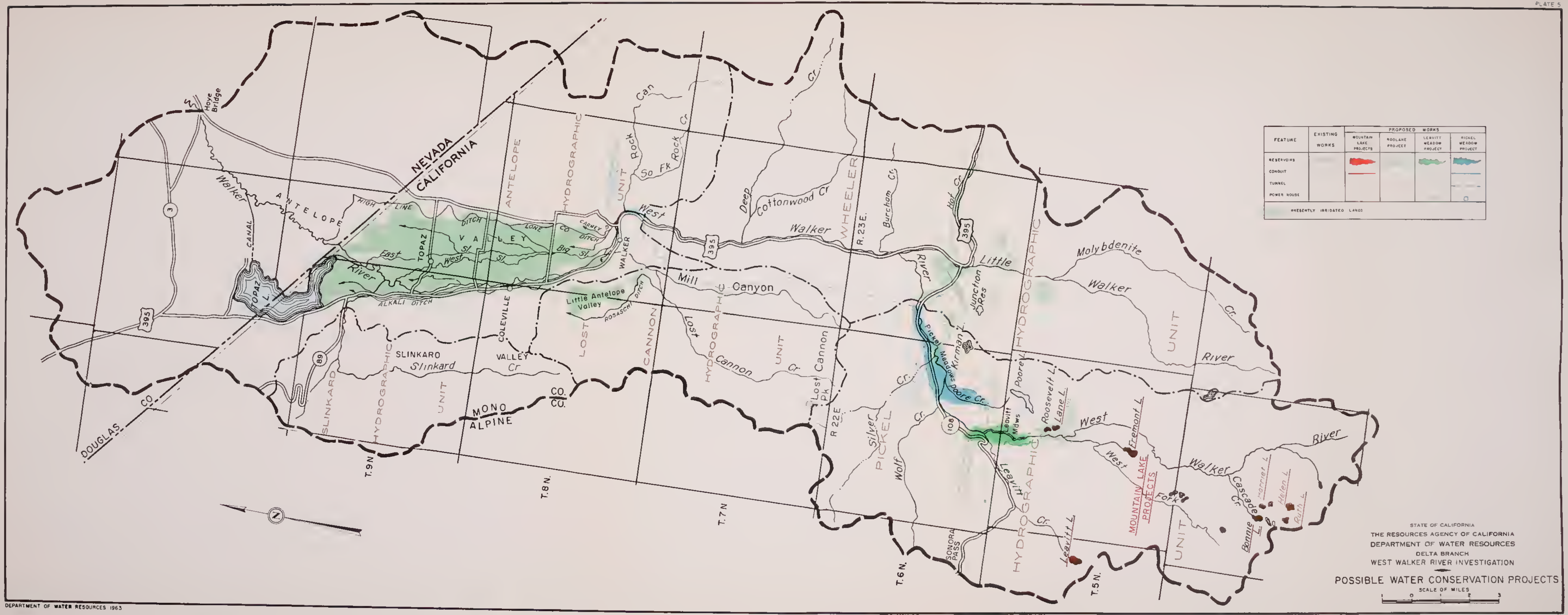
FEATURE
EXISTING WORKS
PROPOSED WORKS
MOUNTAIN LAKE PROJECTS
LEAVITT MEADOW PROJECT
PICKEL MEADOW PROJECT
RESERVOIRS
CONDUIT
TUNNEL
POWER HOUSE
PRESENTLY IRRIGATED LANDS
NEVADA
CALIFORNIA
Hoye Bridge
Walker
CANAL
ANTELOPE
HIGH LINE
DITCH
VALLEY
LONE
CO
CARNEY
DITCH
East
West
Sl.
Big
Sl.
TOPAZ
TOPAZ L.
River
ALKALI DITCH
COLEVILLE
WALKER
West
Walker
Mill
Canyon
Little Antelope Valley
ROSASCHI
DITCH
ANTELOPE
HYDROGRAPHIC
UNIT
Rock
Can
So Fk
Rock
Cr.
Deep
Cottonwood Cr
Burcham
Cr.
Hot
Cr.
Cr.
WHEELER
R. 23 E.
395
395
395
3
89
108
River
Junction Res
Little
Walker
Molybdenite
Cr.
River
UNIT
HYDROGRAPHIC
LOST
CANNON
Lost
HYDROGRAPHIC
Cannon
Cr.
UNIT
Lost Cannon
Lost Cannon Pk
R. 22 E.
SLINKARD
HYDROGRAPHIC
UNIT
SLINKARD
Slinkard
VALLEY
Cr
MONO
ALPINE
CO.
CO.
DOUGLAS
CO.
T. 9 N.
T. 8 N.
T. 7 N.
T. 6 N.
T. 5 N.
N
Silver
PICKEL
Wolf
Cr.
Cr.
Pickel Meadows
Kirman L.
Poore L.
Poore Cr.
Leavitt Mdws
Roosevelt L.
Lane L.
West
Fremont L.
West
Fork
MOUNTAIN LAKE PROJECTS
Leavitt
Cr.
Leavitt L.
SONORA PASS
HYDROGRAPHIC
UNIT
Walker
River
Cascade
Cr.
Bonnie L.
Harriet L.
Helen L.
Ruth L.
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DELTA BRANCH
WEST WALKER RIVER INVESTIGATION
POSSIBLE WATER CONSERVATION PROJECTS
SCALE OF MILES
1 0 1 2 3
DEPARTMENT OF WATER RESOURCES 1963